An aerolance system

WO 2014008549 A1

ABSTRACT

An aerolance system for an aerospace vehicle including a head for positioning adjacent a nose of the aerospace vehicle. The head includes a divergent section and a convergent section wherein a base of the convergent section is positioned adjacent a base of the divergent section, and wherein the head includes a cavity for ejecting fluid out of the head.

CLAIMS (OCR text may contain errors)

1. An aerolance system for an aerospace vehicle including:

a head, for positioning adjacent a nose of the aerospace vehicle, the head including:

a divergent section; and

a convergent section wherein a base of the convergent section is positioned adjacent a base of the divergent section; and

wherein the head includes a cavity for ejecting fluid out of the head.

2. The aerolance system of claim 1 further including a shaft wherein a proximal end of the shaft is connected to a tip of the convergent section.

3. The aerolance system of claim 2 wherein a distal end of the shaft opposite the proximal end of the shaft is for connecting to the aerospace vehicle.

4. The aerolance system of claim 1 wherein a base of the divergent section is connected to a base of the convergent section.

5. The aerolance system of claim 1 wherein the divergent section is conically shaped.

6. The aerolance system of claim 5 wherein an angle of a tip of the divergent section is less than 45.5 degrees.

7. The aerolance system of claim 5 wherein an angle of a tip of the divergent section is less than 41.1 degrees.

8. The aerolance system of claim 2 wherein the shaft is hollow for injecting fluid into the cavity.

9. The aerolance system of claim 2 wherein the cavity includes one or more injectors fluidly connected to the shaft, each injector for diverting fluid to control a manoeuvrability of the aerospace vehicle.

10. The aerolance system of claim 2 wherein the cavity includes a pressure chamber, a contraction region, a throat and an expansion region and wherein, the convergent region compresses and accelerates subsonic fluid flow up to sonic conditions, the throat ensures a transition from subsonic to

supersonic conditions and the expansion region expands the sonic flow to supersonic speeds before being ejected out of the head.

11. The aerolance system of claim 1 wherein a nose of the aerospace vehicle includes a ramped section and an expansion section.

12. The aerolance system of claim 1 further including a spike connected to a tip of the divergent section.

13. The aerolance system of claim 12 wherein a shaft of the spike is connected to the tip of the divergent section.

14. The aerolance system of claim 12 wherein a tip of the spike includes a divergent section.

15. An aerolance system, for an aerospace vehicle, including:

a head, for positioning adjacent a nose of the aerospace vehicle, the head including:

a divergent section; and a convergent section wherein a base of the convergent section is connected to a base of the divergent section; and

wherein a nose of the aerospace vehicle includes a ramped section and an expansion section.

16. The aerolance system of claim 15 wherein an outer surface of the expansion section is convex in shape.

17. The aerolance system of claim 15 wherein an outer surface the expansion section defines a reflex angle.

18. The aerolance system of claim 15 wherein the ramped section extends from an outer edge of a base of the nose to the expansion section.

19. The aerolance system of claim 15 wherein a shaft connects the head to the nose.

20. The aerolance system of claim 15 wherein an outer surface of a tip of the nose is curved.

DESCRIPTION (OCR text may contain errors)

TITLE

AN AEROLANCE SYSTEM

FIELD OF THE INVENTION

This invention relates generally to an aerolance system and in particular an aerolance system for an aerospace vehicle for supersonic or hypersonic flight.

BACKGROUND TO THE INVENTION

Aeronautics has progressed enormously over the past century or so since the Wright brothers' first powered flight in 1903. Aerospace vehicles, such as military aircraft and spacecraft, have been developed that can travel well in excess of the speed of sound. However a problem of travelling at such supersonic and hypersonic speeds is that drag increases rapidly with speed, and results in a heating of the body of the aerospace vehicle and a reduction in fuel efficiency and hence range of the aerospace vehicle.

In order to reduce drag and heating loads on an aerospace vehicle, aerolances have been developed that are attached to the front of the aerospace vehicle. The aerolance includes a conical or frusto-conical head attached to a shaft in order to improve the aerodynamics and improve drag. Some prior art head designs are described in the following US patents.

US patent number 3,643,901 discloses an aerolance with a frusto- conical head, and an aperture extending axially through the entire length of the head in order to reduce drag.

US patent number 4,790,499 also discloses several designs of an aerolance for an aerospace vehicle. In a first embodiment the aerolance includes a head and a shaft for connecting the head to a nose of the aerospace vehicle. The shaft tapers generally from the aerospace vehicle to the head. In one embodiment, the shaft includes a number of sections that telescope inside one another in order to define a taper from the aerospace vehicle to the head.

In a second embodiment, similar to the disclosure of US patent number 3,643,901 , the head is conical in shape and includes an aperture extending axially through the entire length of the head. Fluid is injected through the aperture to improve aerodynamic flow of fluid about a tip of the head.

US patent number 6,581 ,870 discloses a planar, a spherical, an ovular and a teardrop shaped head of an aerolance. Tests show that the planar and the spherical head designs separate flow at approximately 2/3 of the shaft length measured from the head which reduces the pressure and hence the drag.

The reference to any prior art in this specification is not, and should not be taken as, an acknowledgement or any form of suggestion that the prior art forms part of the common general knowledge in Australia or elsewhere.

OBJECT OF THE INVENTION

It is an object, of some embodiments of the present invention, to provide consumers with improvements and advantages over the above described prior art, and/or overcome and alleviate one or more of the above described disadvantages of the prior art, and/or provide a useful commercial choice.

SUMMARY OF THE INVENTION

In one form, although not necessarily the only or broadest form, the invention resides in an aerolance system, for an aerospace vehicle, including:

a head, for positioning adjacent a nose of the aerospace vehicle, the head including:

a divergent section; and a convergent section wherein a base of the convergent section is positioned adjacent a base of the divergent section; and

wherein the head includes a cavity for ejecting fluid out of the head.

Preferably, the cavity is positioned between the divergent section and the convergent section of the head.

Preferably the aerolance system includes a shaft wherein a proximal end of the shaft is connected to a tip of the convergent section.

Preferably a distal end of the shaft opposite the proximal end of the shaft is for connecting to the aerospace vehicle.

Preferably a base of the divergent section is connected to a base of the convergent section.

Preferably, the divergent section is conical in shape.

Preferably, the convergent section is frusto-conical in shape.

Preferably, an angle of a tip of the divergent section is less than 45.5 degrees.

More preferably, an angle of the tip of the divergent section is less than 41.1 degrees.

Preferably, the shaft is hollow for injecting the fluid into the cavity.

Preferably, the cavity includes one or more injectors fluidly connected to the shaft, each injector for diverting fluid to control a manoeuvrability of the aerospace vehicle.

Preferably, the cavity includes a pressure chamber, a contraction region, a throat and an expansion region. The contraction region compresses and accelerates subsonic fluid flow up to sonic conditions, the throat ensures a transition from subsonic to supersonic conditions and the expansion region expands the sonic flow to supersonic speeds before being ejected out of the head.

Preferably, a spike is connected to a tip of the divergent section.

Preferably a tip of the spike includes a divergent section. Preferably, a shaft of the spike is connected to the tip of the divergent section of the head.

Preferably, the nose of the aerospace vehicle includes a ramped section and an expansion section.

Preferably, an outer surface the expansion section is convex in shape. In another embodiment, an outer surface of the expansion section forms a reflex angle.

In another form the invention resides in an aerolance system, for an aerospace vehicle, including:

a head, for positioning adjacent a nose of the aerospace vehicle, the head including:

a divergent section; and

a convergent section wherein a base of the convergent section is connected to a base of the divergent section; and

wherein a nose of the aerospace vehicle includes a ramped section and an expansion section.

Preferably, the head is connected to the nose by a shaft.

Preferably, the expansion section is located between a tip and a base of the nose.

In one embodiment, an outer surface the expansion section is convex in shape. In another embodiment the outer surface of the expansion section defines a reflex angle.

Preferably, the ramped section extends from a base of the nose to the expansion section.

Preferably, an outer surface of a tip of the nose is curved such that it forms a smooth transition from the nose to the shaft. The curved outer surface of the tip allows the re-circulating flow to change direction with minimised pressure build-up in fluid flow. Preferably, the curved outer , surface of the tip is concave.

Preferably the aerolance system includes a shaft wherein a proximal end of the shaft is connected to a tip of the convergent section. Preferably a distal end of the shaft opposite the proximal end of the shaft is for connecting to the aerospace vehicle.

Preferably a base of the divergent section is connected to a base of the convergent section.

Preferably, the divergent section is conical in shape.

Preferably, the convergent section is frusto-conical in shape.

Preferably, an angle of a tip of the divergent section is less than 45.5 degrees.

More preferably, an angle of the tip of the divergent section is less than 41.1 degrees.

Preferably, the head includes a cavity positioned between the convergent section and the divergent section for ejecting fluid out of the head.

Preferably, the shaft is hollow for injecting fluid into the cavity. Preferably, the cavity includes one or more injectors fluidly connected to the shaft, each injector for diverting fluid to control a manoeuvrability of the aerospace vehicle.

Preferably, the cavity includes a pressure chamber, a contraction region, a throat and an expansion region. The contraction region compresses and accelerates subsonic fluid flow up to sonic conditions, the throat ensures a transition from subsonic to supersonic conditions and the expansion region expands the sonic flow to supersonic speeds before being ejected out of the head.

Preferably, a spike is connected to a tip of the divergent section. Preferably a tip of the spike includes a divergent section.

Preferably, a shaft of the spike is connected to the tip of the divergent section of the head.

BRIEF DESCRIPTION OF THE DRAWINGS

To assist in understanding the invention and to enable a person skilled in the art to put the invention into practical effect, preferred embodiments of the invention are described below by way of example only with reference to the accompanying drawings, in which:

FIG 1 illustrates a front perspective view of an aerolance system according to a first embodiment of the present invention;

FIG 2 illustrates a front perspective view of an aerolance system according to a second embodiment of the present invention;

FIG 3A shows a graph of air speed around the aerolance system of

FIG 1 ;

FIG 3B shows the graph of FIG 3A with shading removed; FIG 4A shows a graph of air pressure around the aerolance system of FIG 1 ;

FIG 4B shows the graph of FIG 4A with shading removed;

FIG 5 illustrates a rear perspective view of an aerolance system according to a third embodiment of the present invention;

FIG 6 illustrates a side cut-away view of the aerolance system of

FIG 5;

FIG 7 shows a graph of air speed around an aerolance system and an aerospace vehicle according to a further embodiment of the aerospace vehicle;

FIG 8 shows a graph of air pressure around an aerolance system and an aerospace vehicle according to a further embodiment of the aerospace vehicle;

FIG 9 shows a graph of air speed around an aerolance system and an aerospace vehicle according to another embodiment of the aerospace vehicle; and

FIG 10 shows a graph of air pressure around an aerolance system and an aerospace vehicle according to another embodiment of the aerospace vehicle. DETAILED DESCRIPTION OF THE INVENTION

Elements of the invention are illustrated in concise outline form in the drawings, showing only those specific details that are necessary to understanding the embodiments of the present invention, but so as not to clutter the disclosure with excessive detail that will be obvious to those of ordinary skill in the art in light of the present description.

In this patent specification, adjectives such as first and second, left and right, front and back, top and bottom, etc., are used solely to define one element from another element without necessarily requiring a specific relative position or sequence that is described by the adjectives. Words such as "comprises" or "includes" are not used to define an exclusive set of elements or method steps. Rather, such words merely define a minimum set of elements or method steps included in a particular embodiment of the present invention. It will be appreciated that the invention may be implemented in a variety of ways, and that this description is given by way of example only.

FIG 1 illustrates an aerolance system 10 according to a first embodiment of the present invention. The aerolance system 10 includes a head 20 and a shaft 30, mounted to an aerospace vehicle 40: The aerolance system 10 is used to divert an oncoming fluid or air flow away from a nose of the aerospace vehicle 40 and promote re-circulation of the air. The aerolance system 10 manipulates the re-circulating air flow and reduces surface air pressure on the aerospace vehicle 40, resulting in reduced pressure drag, reduced skin-friction drag and reduced heating loads acting on the aerospace vehicle 40. As such fuel efficiency, range and manoeuvrability of the aerospace vehicle are increased when operating at supersonic and hypersonic speeds.

Referring to FIG 1 , the head 20 includes a divergent section 21 and a convergent section 22. A base 23 of the divergent section 21 , is adjacent to, and connected to a base 24 of the convergent section 22. In one embodiment, a diameter of each base 23, 24 is the same, and is greater than a diameter of the shaft 30. Thus in a preferred embodiment each base is circular forming an annular head. A tip 25 of the convergent section 22 is connected to a proximal end 31 of the shaft 30, and a distal end 32 of the shaft 30 opposite the proximal end 31 is connected to the aerospace vehicle 40.

The divergent section 21 and the convergent section 22 are ramped. In one embodiment, the divergent section 21 is conical in shape and the convergent section 22 is frusto conical in shape. However it should be appreciated that the shape of the divergent section 21 and the convergent section 22 may form other shaped ramped surfaces.

The aerospace vehicle 40 includes a nose 41 and a body 42. In one embodiment, the nose 41 is generally conical in shape, and the body 42 is cylindrical. However it should be appreciated that the present invention may be adapted to be used with differently shaped aerospace vehicles 40, such as an aeroplane. Other shapes of nose 41 are discussed below with reference to FIGs. 7 - 10.

The nose 41 includes an expansion section 43 and a ramped section 44. In addition an outer surface of a tip 45 of the nose 41 is curved, and in particular convex, such that it forms a smooth transition from the nose 41 to the shaft 30. As a result an outer surface of the nose 41 has a point of inflexion 47 between the expansion section 43 and the tip 45. [1]

An outer surface of the expansion section 43 is convex such that it flares or bulges around a circumference of the nose 41. In one embodiment, the expansion section 43 is positioned approximately mid way between the tip 45 and a base 46 of the nose 41 , and the ramped section 44 extends from the expansion section 43 to an edge of the base 46 of the nose 41.

Similar to the head 20, the ramped section 44 of the nose 40 is sloped, and in the embodiment, shown in FIG. 1 , the ramped section 44 is curved. However it should be appreciated that in other embodiments the ramped section may be straight. FIG 2 illustrates an aerolance system 50 according to a second embodiment of the present invention. The aerolance system 50 is similar to the aerolance system 10 of FIG 1 , and includes a head 60, and a shaft 70 connected to an aerospace vehicle 80. In addition, the aerolance system 50 of FIG 2 includes a spike 90. The spike 90 includes a shaft 91 and a tip 92. In one embodiment, the shaft 91 is cylindrical however it should be appreciated that a cross-section of the shaft 91 may be other shapes such as ovular. A further difference to the embodiment of FIG 1 is that a divergent section 61 of the head 60 is frusto conical in shape in order to facilitate connecting the spike 91.

The performance of the aerolance system 10 of FIG 1 is demonstrated in FIGs 3A, 3B, 4A and 4B. FIGs 3A and 3B show a graph 100 of air speed/air flow, and FIGs 4A and 4B show a graph 110 of air pressure around the aerolance system 10 and aerospace vehicle 40 of FIG 1. FIGs 3B and 4B are the same as FIGs 3A and 4A respectively except that shading has been removed from FIGs 3B and 4B. An outline of the aerolance system 10 and the aerospace vehicle 40 is shown as a dashed line 101 , which is a section through A-A of FIG. 1. The effect of each relevant part of the aerolance system 10 and aerospace vehicle 40 on aerodynamics is discussed below.

Referring to FIGs 1 , 3A, 3B, 4A and 4B, the aerolance system 10 is designed so that an attached primary oblique Shockwave 102 misses an edge of the nose 41 of the aerospace vehicle 40. The divergent section 21 of the head 20 'breaks' the air and results in the attached primary oblique Shockwave 102, as shown in FIGs 3A and 3B, and a corresponding increase in pressure 112 as shown in FIGs 4A and 4B. Returning air flow 103, from the nose 41 of the aerospace vehicle 40 to the head 20, results in a pressure build up 113, shown in FIGs 4A and 4B, behind the head 20.

The attached primary oblique Shockwave 102 deflects and slows air flow around the aerospace vehicle 40. The maximum angle Θ of the tip 26 of the divergent section 21 , to generate the attached primary oblique Shockwave 102 for a desired supersonic operating speed, is determined using oblique Shockwave relations, as is known in the art. In one embodiment, for Mach 5 flight, an angle Θ of the tip 26 of the divergent section 21 is less than about 41.5 degrees. 41.5 degrees is the maximum theoretical angle determined from the standard Shockwave relations, thus the angle Θ may be any angle less than 41.5 degrees. In addition, dimensions of the nose 20, shaft 30 and aerospace vehicle 40 are chosen to prevent the attached primary oblique Shockwave 102 from impinging on the aerospace vehicle 40.

The divergent section 21 associated attached primary oblique Shockwave 102 determines a length of the shaft 30 and a diameter, in the case of a cylinder, of the aerospace vehicle 40. For a specified divergent section 21 , the length of the shaft 30 is determined so that the attached primary oblique Shockwave 102 does not impact the vehicle 40.

A diameter of the divergent section 21 is chosen to allow development of full re-circulating fluid or air flow, as shown generally by the direction of the arrowed contour lines in FIGs 3A and 3B. Computational Fluid Dynamics (CFD) may be used to determine an optimal diameter of a base 23 of the divergent section 21 so that the diameter is sufficiently large for the desired operating speed and/or conditions.

The recirculating air flow travels down the aerospace vehicle nose 41 and along the shaft 30 toward the convergent section 22. This air flow is in the opposite direction to air passing over the aerospace vehicle 40. The geometry of the aerospace vehicle 40 must be tuned to achieve the full re-circulating fluid or air flow using CFD for a particular operating point. In one embodiment, a normal Shockwave 104, and an associated increase in pressure 114, is created along a path back towards the head 20. It should be appreciated that not all embodiments may include a normal Shockwave. Most aerospace vehicles and engines for example are designed to perform optimally at a particular flight condition with some trade-offs made for transition conditions. The convergent section 22 allows recirculating air flow to smoothly move towards a recirculating flow from the divergent section 21. The convergent section 22 ensures that the expanding flow does not stagnate (come to rest) behind the head 20. Generally, the present invention reduces sharp angles along various flow paths of the air around the aerospace vehicle 40. The optimal design of convergent section 22 is convergent with respect to the base 23 of the divergent section 21 , and is also not perpendicular to the shaft 30, which may lead to a detrimental vortex formation behind the head 20. A vortex formed in this region can have the deleterious effect of increasing the expansion angle of the flow passing over the head 20.

In one embodiment, the nose 41 of the aerospace vehicle 40 is contoured in order to reduce air pressure at an outer edge of the nose 41. The contoured nose expands recirculating air flow, thereby reducing the pressure on a front surface of the aerospace vehicle.

In one embodiment, the expansion section 43 is convex in shape and expands the re-circulating air flow, thereby reducing air pressure 115 acting on the nose 41 of the aerospace vehicle 40, as shown in FIGs. 4A and 4B. In particular, some air flow travels from the ramped section 44 through the expansion section 43 (where the air flow is expanded) down to the end of the shaft 32 and back towards the head 20. Furthermore, in one embodiment, the nose 40 creates a secondary oblique Shockwave 105.

The ramped section 44 reduces an impact of non-zero angles of attack on the aerospace vehicle drag relative to an end of cylinder or cone. As shown in FIGs. 4A and 4B, this results in a minimised air pressure 116 adjacent the ramped section 44 of the nose 41.

In addition, the ramped section 44 allows the re-circulating air flow to generate skin-friction thrust, and links with the expansion section 43 to reduce air pressure in the front of the aerospace vehicle 40. Furthermore, the curved section at the tip 45 of the nose 41 allows the re-circulating flow to change direction with minimised pressure buildup in the flow.

According to some embodiments, the optimal shape of the nose 41 is between an end of a cylinder i.e. a flat surface, and a conical shape. The end of a cylinder is not robust to changes in an angle of attack leading to high pressure regions on the nose 41 of the aerospace vehicle 40. Furthermore, it also does not direct the re-circulating air flow towards the head 20 thereby limiting drag reduction.

A purely conical shape does not maximise the potential of generating a low-pressure region by expanding the re-circulating air flow. In addition a conical shape does not minimise the pressure in a region where the air flow impinges on the nose 41 of the aerospace vehicle 40.

Additionally, the spike 90 of the aerolance system of FIG 2 further reduces total aerodynamic drag by reducing air pressure on the surface of the divergent section 61. A primary shock generated by the spike tip 92 intersects the shock wave 102 generated at the divergent section 61 with preservation of the flow deflection and recirculation features achieved in the aerolance system of FIG .

In summary, the advantages of the aerolance system are that it reduces pressure and skin friction drag and heating loads acting on an aerospace vehicle. Thus fuel efficiency of the aerospace vehicle 40 is increased resulting in an increased range, reduced running costs and enabling larger payloads to be carried.

FIG 5 shows a rear perspective view and FIG 6 shows a side cutaway view of an aerolance system 120 according to a further embodiment of the present invention. The aerolance system 120 is similar to the aerolance systems 10, 50 of FIGS 1 and 2.

Similar to FIGs 1 and 2, the aerolance system 120 includes a head 130, and a shaft 140 for connecting to an aerospace vehicle (not shown). However, in this embodiment, the shaft 140 is hollow and a cavity 150 is formed between a divergent section 131 and a convergent section 132 of the head 130. It should be appreciated that the cavity 150 may be formed in any suitable part of the head 130, for example the cavity 150 may be formed in the divergent section 131 , or in the convergent section 132. Fluid, or air, is injected through the shaft 140 and into the cavity 150, and ejected out of the cavity 150 between the divergent section 131 and the convergent section 132 out of the head 130. The ejected fluid is used to enhance a deflection of oncoming air flow achieved by the head 130 in order to reduce drag. In addition, by injecting fluid asymmetrically out of the cavity 150, for example between the divergent section 131 and the convergent section 132, it is possible to rapidly change aerodynamic loads on the aerospace vehicle for the purpose of flight control.

As shown in FIG 6, the cavity 150 includes one or more injectors 151 , a pressure chamber 152, a contraction region 153, a throat 154 and an expansion region 155. The contraction region 153 is a narrowing of the cavity 150 and the expansion region 155 is a broadening of the cavity 150. The throat 154 is the transition from the contraction region 153 to the expansion region 155.

The injectors 151 are fluidly connected to, and positioned adjacent a proximal end 141 of the shaft 140. The shaft 140 may include a number of individual supply lines (not shown) to provide fluid independently to each injector 151.

The pressure chamber 152 is fluidly connected to the contraction region 153, and the contraction region 153 is fluidly connected to the expansion region 155 via the throat 154.

In use high pressure fluid is delivered via the shaft 140 into the pressure chamber 152 (potentially generated via combustion) and is ejected through head 130. Alternatively, solid or liquid propellant may be combusted in the head 130 and ejected through the head 130 to form a ring of a high-speed fluid flow between the divergent section 131 and the convergent section 132 of the head 130.

The contraction region 153 compresses and accelerates subsonic fluid flow up to sonic conditions at the throat 154. The throat 154 chokes exiting fluid flow (at Mach 1) ensuring a transition from subsonic to supersonic conditions. The dimensions of the throat 154 are a function of air flow properties of the divergent section 131 of the head 130.

The expansion region 155 expands the sonic fluid flow to supersonic speeds before being ejected out of the head 130. The internal shape of the expansion region is dictated by the desired operating conditions and may be a function of the ejected and free-stream air flow properties and the geometry of a nose of the aerospace vehicle (not shown) and the aerolance system 120. In particular, the length of the shaft 140, the diameter of the aerospace vehicle and size of the head 130 combine to determine an angle of ejected fluid flow. The geometry of the head 130 impacts the design by limiting a mean ejection angle as it is not desirable to aim the ejected flow directly onto the nose of the aerospace vehicle.

Similar to the first embodiment, the aerolance system 120 provides drag reduction. However in this embodiment, the aerolance system 120 provides extra drag reduction by ejecting a high pressure fluid generated from a reservoir or via combustion into the external fluid flow field through the head 130. The ejected high-speed fluid flow reduces the expansion of the air flow around the head 130. This minimises a redirection of highspeed external air flow toward a body of the aerospace vehicle. In addition, some propulsion is generated by the flow ejected through the head 130. The re-circulating air flow field is altered by the changed expansion of air flow around the head 130 and the ejected high-speed flow from the head 130.

In addition to reducing drag, the aerolance system 120 may be used for manoeuvring the aerospace vehicle. This is achieved by asymmetrically ejecting fluid flow from the head 130 to produce asymmetric aerodynamic loads on the aerospace vehicle. This facilitates rapid flight control actuation at hypersonic speeds. Asymmetrical fluid flow may be achieved by blocking an injector 151 or by only allowing a nominated injector 151 to release flow (i.e. blocking the remaining injectors 151 of the head 130). Alternatively, sections of the head 130 can be blocked by electro-mechanical or pneumatic actuated panels (not shown). The panels are used to block the contraction region 153, throat 154 and/or expansion regions 155 of the nozzle. This may involve panels moving from the aerospace vehicle-end of the head 130, forward along the axis of the shaft 140 to block flow through contraction region 153, throat 154 and expansion regions 155 of the head 130. Blockage of segments of the nozzle can provide control in 1 or 2 planes of motion i.e. control of pitch and/or yaw of an aerospace vehicle.

Although FIGs 5 and 6 show that the pressure chamber is open to all of the injectors 151 , it should be appreciated that, in order to work effectively, the pressure chamber 152 should be compartmentalised for each injector 151 , otherwise a largely uniform pressure may exist in the pressure chamber 152 when some injectors 151 are blocked. The compartments may be formed using veins installed in the pressure chamber 152.

As discussed previously, the nose of the aerospace vehicle is contoured, and includes an expansion section and a ramped section. FIGs. 7-10 show the aerodynamic performance of further embodiments of the nose of the aerospace vehicle. In the embodiments shown in FIGs. 7- 10, the aerolance system 10 is the same as that shown in FIG. 1 , and the aerolance system 10 and the aerospace vehicle are shown in dotted outline through a longitudinal section of the aerolance system 10 and the aerospace vehicle. It should be appreciated that the head and shaft may be similar to the embodiments illustrated in FIGs. 5 and 6.

FIG. 7 shows a graph 160 of air speed around the aerolance system 10 and an aerospace vehicle 180, and FIG. 8 shows a graph 170 of air pressure around the aerolance system 10 and the aerospace vehicle 180 according to a further embodiment of the aerospace vehicle 180. Similar to the embodiment shown in FIG. 1 , the aerospace vehicle 180 includes a nose 181 and a body 182.

Similar to FIG. 1 , the nose 181 includes an expansion section 183 and a ramped section 184. However in this embodiment the nose 181 is defined by a series of straight sections such that the expansion section 183 defines a reflex embodiment the nose 181 is defined by a series of straight sections such that the expansion section 183 defines a reflex angle.

A flat portion 185 extends perpendicularly from the shaft 30 to the ramped section 184 approximately midway between the shaft 30 and an edge of the body 182 of the aerospace vehicle 180. The ramped section 184 slopes rearwards from an end of the flat portion 185, opposite to the shaft 30, to the edge of the body 182. In this embodiment, the expansion section 183 is defined by a transition from the ramped section 184 to the flat portion 185.

Similar to previous embodiments, the combination of the head 20 and the nose 181 facilitates a recirculating air or fluid flow from the nose 181 towards the head 10 and back towards the body 182 of the aerospace vehicle 180, creating a "bubble" of recirculating fluid flow. In addition, as shown in FIG. 7, the nose 181 creates a vortex 166 infront of the nose 181 that deflects recirculating flow travelling down the nose 181 towards the head 20, separating the recirculating flow from the nose 181. As a result, as shown in FIG. 8, air pressure 176, adjacent the nose 181 , is reduced.

FIG. 9 shows a graph 190 of air speed around the aerolance system 10 and an aerospace vehicle 210, and FIG. 10 shows a graph 200 of air pressure around the aerolance system 10 and the aerospace vehicle 210 according to another embodiment of the aerospace vehicle 210. Similar to the embodiment shown in FIG. 1 , the aerospace vehicle 210 includes a nose 211 and a body 212.

Similar to other embodiments, the nose 211 includes an expansion section 213 and a ramped section 214.. However in this embodiment, the expansion section 213 is defined by a transition from the ramped section 214 to a recess 215, such that the expansion section 213 defines a reflex angle. The recess 215 extends between the shaft 30 and the ramped section 214, and includes a flat portion 245A extending perpendicularly from the shaft 30 towards an edge of the body 212, and a ramped portion 215B. The ramped portion 215B, slopes towards the head 20 from an end of the flat portion 215A opposite to the shaft 30, to the ramped section 214 at an obtuse angle.

A first portion of the ramped section 214 slopes rearwards at an acute angle from the ramped portion 215B of the recess 215, towards the edge of the body 212. A second portion of the ramped section 214, towards an edge of the body 212, extends at an obtuse angle from the first portion to the edge of the body 212.

Similar to previous embodiments, the combination of the head 20 and the nose 211 facilitates a recirculating air or fluid flow from the nose 211 towards the head 10 and back towards the body 212 of the aerospace vehicle 210, creating a "bubble" of recirculating fluid flow. In addition, as shown in FIG. 9, the contoured nose 211 creates a vortex 196 infront of the nose 211 that deflects recirculating flow travelling down the nose 211 towards the head 20, separating the recirculating flow from the nose 211. As a result, as shown in FIG. 10, air pressure 176 adjacent the nose 211 is reduced.

Although specific configurations of a nose are shown in FIGs. 1-4, and 7 to 10, it should be appreciated that the nose may be contoured in any suitable configuration that includes a ramped section and an expansion section. Such other designs may be verified using CFD to ensure the aerodynamic characteristics are similar to those described in this specification.

In summary, the aerolance system provides, at least, the following advantages:

1) Drag is reduced and results in a reduction in fuel consumption and hence a reduction in operating costs;

2) The range of the aerospace vehicle is increased and/or the aerospace vehicle may carry larger payloads; and 3) In some embodiments, the aerolance system may be used to manoeuvre the aerospace vehicle.

The above description of various embodiments of the present invention is provided for purposes of description to one of ordinary skill in the related art. It is not intended to be exhaustive or to limit the invention to a single disclosed embodiment. As mentioned above, numerous alternatives and variations to the present invention will be apparent to those skilled in the art of the above teaching. Accordingly, while some alternative embodiments have been discussed specifically, other embodiments will be apparent or relatively easily developed by those of ordinary skill in the art. Accordingly, this patent specification is intended to embrace all alternatives, modifications and variations of the present invention that have been discussed herein, and other embodiments that fall within the spirit and scope of the above described invention.

PATENT CITATIONS

Cited Patent	Filing date	Publication date	Applicant	Title
US3643901 *	May 27, 1970	Feb 22, 1972	Patapis Isidor C	Ducted spike diffuser
US4790499 *	Oct 31, 1986	Dec 13, 1988	Taylor Thomas C	Aerospike for attachment to space vehicle system
US6581870 *	Nov 8, 2000	Jun 24, 2003	Lfk Lenkflugkoerpersysteme Gmbh	Method and apparatus for reducing pressure and temperature on the front of a missile at ultrasonic speed

* Cited by examiner

NON-PATENT CITATIONS

		Reference
1	*	MARK D. WATERMAN ET AL. DEVELOPMENT OF THE TRIDENT I AERODYNAMIC SPIKE MECHANISM pages 39 - 48

* Cited by examiner

CLASSIFICATIONS

International Classification	B64C23/04, B64C1/38, B64C19/00, B64C39/00, B64C30/00, B64C17/00, B64C15/00
Cooperative Classification	B64C30/00

LEGAL EVENTS

Date	Code	Event	Description
Mar 12, 2014	121		Ref document number: 13816359 Country of ref document: EP Kind code of ref document: A1