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[54] VARIABLE DEFLECTION THRUSTERS FOR JETS

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[52] U.S. Cl. ....244/42 CC
[51] Int. Cl. B64c 21/04
[58] Field of Search ....244/42 R, 42 CD, 42 CC, 42 C, 244/40, 41

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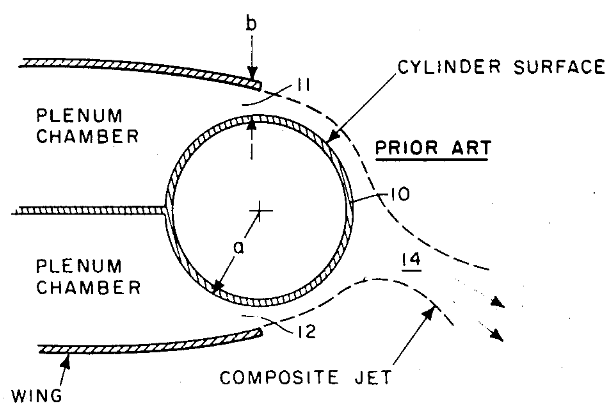
[57] ABSTRACT

Variable deflection thrusters center body of improved design for jets for overcoming stream detachment at high mach numbers and high pressure ratios.

2 Claims, 4 Drawing Figures



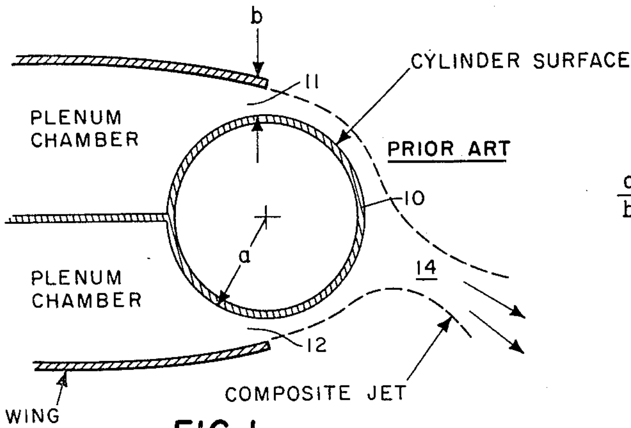


FIG. 1

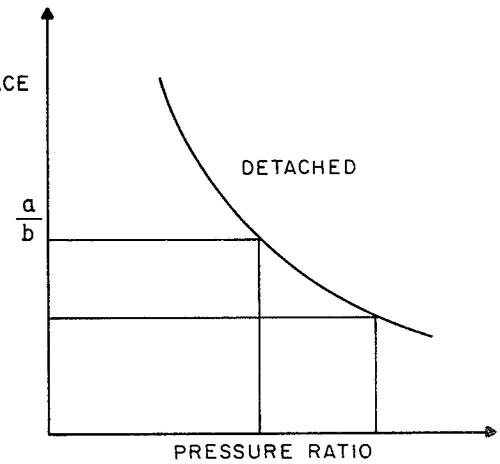


FIG. 2

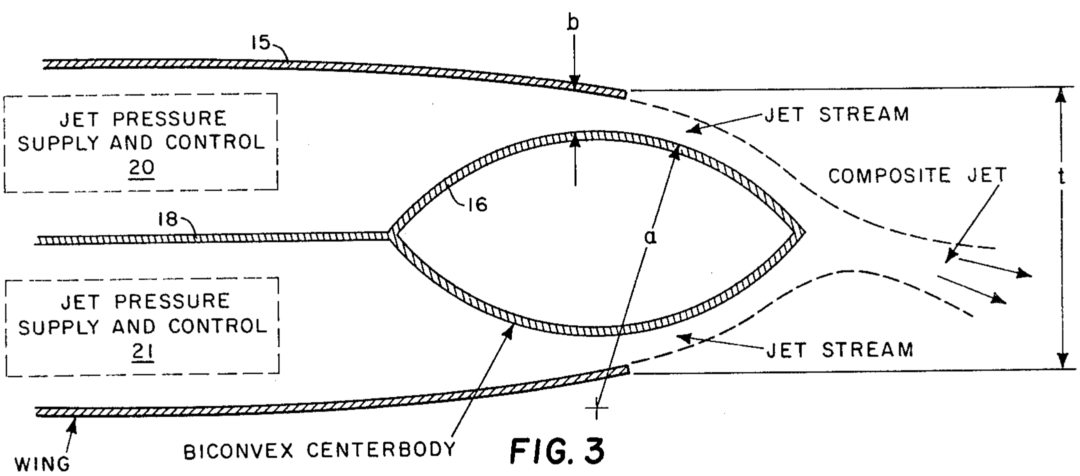


FIG. 3

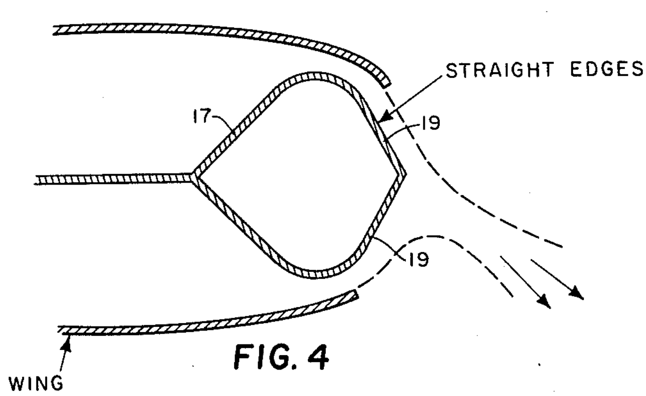


FIG. 4

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VARIABLE DEFLECTION THRUSTERS FOR JETS

The invention herein described may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment of any royalties thereon or therefor.

The basic variable deflection thruster (VDT) concept is disclosed by Davidson U.S. Pat. No. 3,062,483 and comprises a curved two-dimensional surface and two nozzles for directing fluid streams tangent to the surface. The streams attach to the surface due to the Coanda effect, and flow around the surface to impinge on each other to form one stream which then exits from the surface in a direction determined by the relative momenta of the original two streams. The net effect is a fluid stream whose direction and strength can be varied by fluid means without the use of mechanical swivels, etc.. Attachment, also called the Coanda effect, is essential for the operation of the VDT, and was first described by Coanda in U.S. Pat. No. 2,052,869. It depends upon entrainment of flow along the jet, depletion of the ambient fluid between the jet and the attachment wall, and subsequent pressure differential across the jet which is directly responsible for the attachment.

However, when the momentum of the jet is too great and the radius of curvature too small, the stream will not attach, but will flow straight past the curved surface. It is this problem which is encountered with conventional VDT's using circular cross-sectioned surfaces shown in FIG. 1. The present invention overcomes this problem with the biconvex VDT and straight edge VDT disclosed herein. A VDT surface shaped like a football cross-section has been found to overcome stream detachment at high mach numbers and high pressure ratios.

Other objects and many of the attendant advantages of this invention will become readily appreciated as the same becomes better understood by reference to the following detailed description when considered in connection with the accompanying drawings wherein:

FIG. 1 shows a conventional VDT design.

FIG. 2 shows pressure ratio vs. nozzle and VDT dimensions.

FIG. 3 shows a preferred embodiment of the invention using a biconvex VDT center body.

FIG. 4 shows a straight edge VDT center body.

The conventional VDT basic configuration shown in FIG. 1 consists of a cylindrical surface **10** on which two jets, issuing from diametrically opposed spanwise-extending discharge apertures or nozzles **11** and **12**, attach. The two jets meet on the surface of cylinder **10** at a position determined by their pressure difference. The jets subsequently form a single combined jet **14** which leaves cylinder surface **10** at some predetermined angle. The exiting angle of the combined jet **14** changes as a result of the bending imposed by the unequal static pressures of the two half-jets.

It is essential in the operation of this VDT configuration (which allows maximum jet deflection) that the two half-jets remain attached to the cylinder surface. Each one of these jets clings to the cylinder surface **10** by virtue of the Coanda effect. The limits of jet attachment are determined by the jet pressure and the geometry of the configuration. Large slots or nozzles, large pressures, and small-diameter Coanda cylinders tend to cause jet detachment.

Because of the importance of jet detachment upon VDT operation, tests were undertaken to determine the flow and geometrical parameters which control the detachment of a single Coanda jet. The VDT jet detaches when for a given geometry the pressure ratio of the jets is increased beyond a given value, thus spoiling the VDT effect. For a fixed nozzle width "b", the greater the radius "a" of cylinder **10** the higher the pressure ratio that the jet can support before it detaches, see FIG. 2.

When the thickness "t" of an airfoil **15** is limited it has been found that a biconvex VDT can be used as shown in FIG. 3 to support a higher pressure ratio jet from apertures **11** and **12** than would be otherwise possible. This biconvex centerbody **16** forms a sharp trailing edge which overcomes the stream detachment occurring with a cylindrical VDT at high mach numbers and high pressure ratios. The biconvex VDT **16** is attached to plate **18** that separates the two plenum chambers within the airfoil **15**, from which the high pressure jets are supplied. Jet pressure supply is provided to the plenum chambers on either side of plate **18**. Jet pressure supplies **20** and **21** are controlled to vary the flow of the jet streams from apertures **11** and **12** relative to each other.

A variable deflection thruster center body **17** having two flat sides **19** which intersect to form a wedge can also be used to solve the stream detachment problems encountered with the conventional circular VDT surface. The attached jets do not operate on the Coanda effect but rather follow the straight edges of the center body **17**. The straight walls **19** of this embodiment shown in FIG. **4** are a limiting case of increasing the radius of curvature until a straight line is approached. The two jets of the straight edge VDT flow along the walls to meet with a pure momentum interchange type of stream interaction.

The Coanda effect is not present when a jet is flowing along side a flat surface. Either a curved surface, or a "recess" or "offset" such as is employed in the nozzle and interaction region of a fluid amplifier, is necessary for the Coanda effect. That is, there must be a "bubble" from which depletion of fluid occurs so as to generate a pressure differential. In the embodiment of FIG. **4**, the Coanda effect is not present, and operation of the invention depends upon stream interaction, also known as momentum interchange. In conventional curved surface VDTs both the Coanda effect and the momentum interchange effects are utilized. Both the biconvex design of FIG. **3** and straight edge design of FIG. **4** form a sharp wedge where the sides come together eliminating problems encountered with a conventional circular VDT surface.

The biconvex VDT device has good lift-production capability up to mach number 0.5. The VDT configuration with straight surfaces (FIG. 4) can eliminate jet detachment problems at high transonic and supersonic speeds.

What is claimed is:

1. An improved variable deflection thruster at the rearward end of an airfoil for use at high subsonic speeds without jet detachment, comprising:

a. an airfoil having opposite first and second side surfaces substantially merging at the rearward end of the airfoil into a sharp trailing edge,

b. said rearward sharp trailing edge being formed from one side edge of a biconvex centerbody,

c. first and second spanwise-extending jet discharge apertures in said airfoil, one said jet discharge aperture being on each side of said biconvex centerbody which forms said trailing edge,

d. each of said first and second jet discharge apertures being shaped and arranged to discharge a fluid stream as a layer rearwardly over the surfaces of said biconvex centerbody,

e. first and second jet pressure supply and control means to provide a fluid jet stream from each said first and second jet discharge apertures, respectively, and to vary the flow of said jet streams discharged from said apertures relative to one another.

2. An improved variable deflection thruster at the rearward end of an airfoil for use at high transonic and supersonic speeds without jet detachment, comprising:

a. an airfoil having opposite first and second side surfaces substantially merging at the rearward end of the airfoil into a wedge shaped trailing edge,

b. said rearward wedge shaped trailing edge being formed by a variable deflection thruster centerbody having two flat sides which intersect to form a wedge,

c. first and second spanwise-extending jet discharge apertures in said airfoil, one said jet discharge aperture being on each side of said variable deflection thruster centerbody having two flat sides which intersect to form said wedge shaped trailing edge,

d. each of said first and second jet discharge apertures being shaped and arranged to discharge a fluid stream as a layer rearwardly over the flat surfaces of said variable deflection thruster centerbody,

e. first and second jet pressure supply and control means to provide a fluid jet stream from each said first and second jet discharge apertures, respectively, and to vary the flow of said jet streams discharged from said apertures relative to one another.

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