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United States Patent	12392304
Kind Code	B2
Date of Patent	August 19, 2025
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Acoustic attenuation vanes for fan ducts in an aircraft

Abstract

An engine of an aircraft comprising an engine core that produces thrust to propel the aircraft. A fan duct extends along a length of the engine core and is positioned between an engine core nacelle and a fan nacelle with the fan duct. A thrust reverser is positioned along the fan duct and has blocker doors and drag links. The thrust reverser is positionable between an open position and a closed position. The open position locates the blocker doors for the air to move along the fan duct and exit at the nozzle exit. The closed position locates the blocker doors across the fan duct to direct the air out of the fan duct through an opening in the fan nacelle. An acoustic attenuation system is mounted in the fan duct and positioned between the thrust reverser and the nozzle exit with the acoustic attenuation system configured to reduce noise caused by fan blade-pass frequency moving through the fan duct.

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Appl. No.:	**18/531063**
Filed:	**December 06, 2023**

Prior Publication Data

Document Identifier	**Publication Date**
US 20250188888 A1	Jun. 12, 2025

Publication Classification

Int. Cl.: **F02K1/70** (20060101); **F02K1/82** (20060101); F02K1/72 (20060101)

U.S. Cl.:

CPC **F02K1/70** (20130101); **F02K1/827** (20130101); F02K1/72 (20130101)

Field of Classification Search

CPC: F02K (1/70); F02K (1/72); F02K (1/827)

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Background/Summary

TECHNOLOGICAL FIELD

(1) The present disclosure relates generally to the field of noise reduction for aircraft and, more specifically, to placing acoustic vanes along within a fan duct in an aircraft engine.

BACKGROUND

(2) Noise regulations limit the allowable noise levels for airports. The noise regulations limit the impact of aircraft noise on communities that are located near the airports. Various federal and local authorities establish the maximum allowable noise for a given time of the day. Normally, allowable noise levels are higher during the daytime and are reduced during evening and nighttime hours.

Some airports have microphones installed around their grounds to monitor the noise levels. Monetary fines or other measures can be taken to enforce the regulations.
(3) Aircraft are designed to reduce the amount of noise that is made during operation. Some existing designs position noise reducing materials within the engines. Some designs rely on hollow structures with perforated face sheets integrated into a housing that extends around the engine. The thickness of a material is often proportional to the fan blade-pass frequency characteristics with a thicker material providing lower frequency noise reduction than a thinner material that targets higher frequency noise. However, thicker materials often lead to difficulties. One issue is forming a relatively thick material with internal structures such as cells and core that is effective in reducing noise. The thicker materials are often difficult to design effectively and/or manufacture. Further, the attachment of thicker materials to the engine housing can interfere with the integration of the engine core mounted accessories. The material can encroach on components of the engine. This encroachment limits the thickness that is available for use in a material to reduce the noise.
(4) Therefore, there is a need for designs that reduce noise and are able to be effectively designed and manufactured. The designs also are configured to allow for engine operation without interfering with the operation.
SUMMARY
(5) One aspect is directed to an engine of an aircraft comprising a fan and an engine core that produces thrust to propel the aircraft. A fan duct positioned downstream from the fan and extends along a length of the engine core and is positioned between an engine core nacelle inner wall and a fan nacelle with the fan duct comprising an inlet and a nozzle exit. A thrust reverser is positioned along the fan duct and comprises a plurality of blocker doors and drag links. The thrust reverser is positionable between an open position and a closed position. The open position locates the blocker doors for the air to move along the fan duct and exit at the nozzle exit. The closed position locates the blocker doors across the fan duct to direct the air out of the fan duct through an opening in the fan nacelle. An acoustic attenuation system is mounted in the fan duct and positioned between the thrust reverser and the nozzle exit with the acoustic attenuation system configured to reduce fan blade-pass frequency noise caused by the fan.
(6) In another aspect, the acoustic attenuation system comprises acoustic vanes positioned along the fan duct aft of the blocker doors and the drag links.
(7) In another aspect, the acoustic vanes are radially aligned in the fan duct around the engine core nacelle inner wall and connected to a wall of the fan duct.
(8) In another aspect, the acoustic vanes comprise a forward end that is tapered, an opposing aft end, an inner lateral side, and an outer lateral side with the outer lateral side mounted to a wall of the fan duct.
(9) In another aspect, the forward end of each of the acoustic vanes is radially aligned with one of the drag links for the acoustic vanes to be positioned in the fan duct in disturbed air flow.
(10) In another aspect, the acoustic vanes comprise a height that is less than a width of the fan duct for the inner lateral sides to be exposed within the fan duct.
(11) In another aspect, the acoustic vanes comprise a forward end and an aft end with the aft ends aligned with a plane aligned at the nozzle exit.
(12) In another aspect, the fan nacelle comprises a forward section that is fixed and an aft section that translates along the fan duct with the acoustic attenuation system mounted to the aft section.
(13) In another aspect, the acoustic vanes comprise a forward end, an opposing aft end, an inner lateral side, and an outer lateral side with the acoustic vanes comprising a shape that is curved between the inner lateral side and the outer lateral side.
(14) One aspect is directed to an engine of an aircraft comprising a fan and an engine core configured to produce thrust to propel the aircraft. A fan duct extends along the engine core downstream from the fan. Blocker doors are mounted in the fan duct. Drag links are mounted in the fan duct and connected to the blocker doors with the drag links configured to move the blocker

doors between an open position to direct airflow along the fan duct and a closed position to direct air out of the fan duct. Acoustic vanes are mounted in the fan duct aft of the drag links and radially aligned with the drag links with the acoustic vanes positioned in disturbed air caused by the drag links.
(15) In another aspect, the acoustic vanes comprise a forward end and a trailing end and are positioned in the fan duct with the forward ends radially aligned with the drag links.
(16) In another aspect, the acoustic vanes comprise a flat shape with an inner lateral side that is straight and with the inner lateral sides aligned with the drag links.
(17) In another aspect, further comprising a fan nacelle with a forward section that is fixed relative to the fan duct and an aft section that translates relative to the fan duct with the acoustic vanes mounted on the aft section of the fan nacelle.
(18) In another aspect, the acoustic vanes comprise: a first section mounted to and extending outward into the fan duct from a first side wall of the fan duct; a second section mounted to and extending outward into the fan duct from a second side wall of the fan duct; and with the first section and the second section aligned on opposing sides of the fan duct and comprising inner lateral sides that face together.
(19) In another aspect, the inner lateral sides of the first section and the second section abut together.
(20) One aspect is directed to a method of reducing noise of an engine of an aircraft. The method comprises: mounting acoustic vanes in a fan duct of the engine with the acoustic vanes positioned aft of drag links of a reverse thruster and positioned in disturbed air caused by the drag links; positioning the drag links in a first position and positioning blocker doors in an open position to enable airflow through the fan duct from an inlet to an nozzle exit; positioning the drag links in a second position and positioning the blocker doors in a closed position to direct the airflow in the fan duct away from the nozzle exit.
(21) In another aspect, the method further comprises moving the drag links between the first and second positions and the blocker doors between the open position and the closed position without moving the acoustic vanes.
(22) In another aspect, the method further comprises translating the acoustic vanes along the fan duct while moving the drag links from the first position to the second position.
(23) In another aspect, each of the acoustic vanes comprises an inner section and an outer section and the method further comprising translating the inner section relative to the outer section when moving the drag links from the first position to the second position.
(24) In another aspect, the method further comprises maintaining the inner sections of the acoustic vanes in fixed positions while translating the outer sections.
(25) The features, functions and advantages that have been discussed can be achieved independently in various aspects or may be combined in yet other aspects, further details of which can be seen with reference to the following description and the drawings.

Description

BRIEF DESCRIPTION OF THE DRAWINGS
(1) FIG. **1** is an isometric view of an aircraft with a pair of engines.
(2) FIG. **2** is a side schematic view of an engine with an acoustic attenuation system positioned in a fan duct.
(3) FIG. **3** is a side schematic view of the engine of FIG. **2** with a thrust reverser engaged to divert the airflow in the fan duct.
(4) FIG. **4** is a schematic perspective view of an acoustic vane.
(5) FIG. **5** is a partial front view of acoustic vanes mounted in a fan duct and radially aligned with

drag links of a thrust reverser.
(6) FIG. **6** is a partial end view in an aft direction of acoustic vanes with a first section and a second section and mounted in a fan duct.
(7) FIG. **7** is a partial end view in an aft direction of acoustic vanes mounted in a fan duct and longitudinally aligned with an aft end of a fan nacelle.
(8) FIG. **8** is a schematic perspective view of an acoustic vane.
(9) FIG. **9** is a flowchart diagram of a method of reducing engine noise of an aircraft.

DETAILED DESCRIPTION

(10) FIG. **1** illustrates an aircraft **100** configured to transport passengers and/or cargo. The aircraft **100** generally includes a fuselage **101** with a flight deck **102** configured to accommodate flight personnel to control the flight. Engines **20** are mounted on the wings **103** on opposing sides of the fuselage **101**.
(11) A variety of different engines **20** can power the aircraft **100**. In some examples, the engines **20** are gas turbine engines. FIG. **2** schematically illustrates an engine **20** with certain features that would be blocked from view being illustrated in broken lines. The engine **20** includes an engine core **21** surrounded by a core nacelle inner wall **22**. Components of the engine core **21** rotate about a longitudinal axis L to power a fan **23** arranged in front of the engine core **21**. The fan **23** is surrounded by a fan nacelle **24** that includes a forward end **61** and an aft end **62**. The fan nacelle **24** includes a fixed section **26** such as in the form of an inlet cowl at a forward portion of the fan nacelle **24**. The fan nacelle **24** also includes a translating section such as in the form of a translating sleeve **27** at an aft end. A portion of the air that enters the engine **20** and passes the fan **23** enters the engine core **21** (as indicated by arrows A). The remainder of the air enters a fan duct **25** that extends around the engine core **21** (as indicated by arrows B).
(12) The engine **20** is equipped with a thrust reverser **30** configured to reverse or divert an aircraft engine's thrust, so that it is directed in a forward direction rather than in an aft direction. The thrust reverser **30** helps to slow the aircraft **100** just after landing or touchdown to reduce wear on the brakes and help to enable shorter landing distances. FIG. **2** illustrates the thrust reverser **30** in an idle state such as during flight. The sleeve **27** is positioned forward against the fixed section **26** of the fan nacelle **24**. Blocker doors **31** are positioned to allow for airflow through the length of the fan duet **25** and out through an nozzle exit **29** at an aft end. One or more drag links **32** are connected to the blocker doors **31**. The drag links **32** include a first end **36** that is connected to the core nacelle inner wall **22** and/or the engine core **21**. The drag links **32** also include a second end **37** that is mounted to the blocker door **31**. FIG. **2** illustrates the drag links **32** in a first orientation that extends across the fan duct **25** and positions the blocker doors **31** in the open position.
(13) FIG. **3** illustrates the thrust reverser **30** in a deployed state. Actuators **33** cause the sleeve **27** to translate in an aft direction to form an opening **34** between the fixed section **26** and the sleeve **27**. The drag links **32** are actuated to a second orientation to position the blocker doors **31** across the fan duct **25**. This position forces the air through the opening **34**. The air flows through cascade members **35** such as in the form of cascade vanes and exits the fan nacelle **24** as reverse efflux air flow.
(14) An acoustic attenuation system **40** is positioned in the fan duct **25** aft of the blocker doors **31**. The acoustic attenuation system **40** functions to control the sound that is produced by the fan **23**. In some examples, the acoustic attenuation system **40** lessens the sound produced by the fan **23** thus allowing the aircraft **100** to meet noise regulations. The acoustic attenuation system **40** comprises one or more acoustic vanes that extend into the fan duct **25**. The number of acoustic vanes and the positioning can vary depending upon the desired noise attenuation. In some examples, the acoustic vanes are positioned radially completely around the engine core **21**. In other examples, the acoustic vanes are positioned radially around one or more limited sections of the engine core **21**. The longitudinal positioning of the acoustic vanes can vary between the blocker doors **31** and the nozzle exit **29** of the fan duct **25**.

(15) FIG. **4** schematically illustrates a vane **41** that is part of the acoustic attenuation system **40**. The vane **41** includes a forward end **42** that is positioned in a forward direction in the fan duct **25**, and an opposing aft end **43**. In some examples, one or both of the forward end **42** and aft end **43** include a tapered shape to direct the airflow. The vane **41** includes a length L measured between the ends **42**, **43**. When the vane **41** is mounted to the core nacelle inner wall **22**, an inner lateral side **44** is positioned inward into the fan duct **25** and an outer lateral side **45** is positioned away from the fan duct **25**, such as against the core nacelle inner wall **22** or sleeve **27**. A height H is measured between the sides **44**, **45**. The vane **41** can be constructed according to standard fabrication methods. In some examples, the vane **41** is substantially flat and can have a range of depths to meet frequency targets.
(16) The number of fan blades and their rotational speed determines a characteristic fan blade-pass frequency for a given engine manufacture and configuration. The acoustic vanes **41** can include various thicknesses to tailor the acoustic performance. In some examples, the thickness of the acoustic vanes **41** is set to target the characteristic blade-pass frequency. Lower targeted frequencies are attenuated by thicker vane or nacelle wall designs. In some examples that target multiple frequencies, the acoustic vanes **41** include different thicknesses. The amount of surface area that is acoustically treated in conjunction with the thickness for the targeted frequency can be designed to increase or decrease the amount of acoustic attenuation.
(17) The acoustic attenuation system **40** can include various numbers of acoustic vanes **41** to match the acoustic needs. The configuration of the acoustic vanes **41** can be adjusted to address induced tones due to their presence in the airflow.
(18) In some examples, the acoustic vanes **41** are radially aligned with the drag links **32** in the fan duct **25**. The acoustic vanes **41** are positioned aft of the drag links **32** which locates the acoustic vanes **41** in the already disturbed air flow. This positioning can provide protection to the forward end **42** of the acoustic vanes **41**. In other examples, the acoustic vanes **41** are radially offset from the drag links **32**. In some examples, the entirety of the acoustic vanes **41** are aligned with the drag links **32**. In other examples, the forward end **42** is aligned with the drag links **32** with other sections misaligned, such as the aft end **43**.
(19) FIG. **5** is a view looking into the fan duct **25** from the front of the engine. Acoustic vanes **41** are positioned in the fan duct **25** and radially aligned around the engine core **21**. The acoustic vanes **41** are radially aligned in the fan duct **25** with the drag links **32**. The acoustic vanes **41** are positioned aft of the drag links **32**. This positioning does not interfere with the operation of the drag links **32** and blocker doors **31**.
(20) In the example of FIG. **5**, the acoustic vanes **41** are mounted to an outer side of the fan duct **25**. In some examples, the outer lateral side **45** of the acoustic vanes **41** are mounted to the sleeve **27**. In another example, the acoustic vanes **41** are mounted to other structural members at the outer side of the fan duct **25**. In some examples, the acoustic vanes **41** are mounted to the sleeve **27** and translate during movement of the sleeve **27**. In other examples, the acoustic vanes **41** are connected to a structural member that does not translate during actuation of the thrust reverser **30**.
(21) In another example, the acoustic vanes **41** are connected to an inner side of the fan duct **25**. In some examples, this includes the outer lateral side **45** mounted to the core nacelle inner wall **22**, or other structural member.
(22) In some examples, the height H of the acoustic vanes **41** is less than the width of the fan duct **25**. This difference in size provides for the inner lateral side **44** to be exposed within the fan duct **25**. In other examples, the acoustic vanes **41** are sized to extend across the width of the fan duct **25** with the outer lateral side **45** connected to one side of the fan duct **25** and the inner lateral side **44** connected to the opposing side of the fan duct **25**.
(23) FIG. **6** illustrates an example in which the acoustic vanes **41** are formed by two sections **41***a*, **41***b*. The first section **41***a* is mounted to the inner side of the fan duct **25**, such as the core nacelle inner wall **22**. The second section **41***b* is mounted to an outer side of the fan duct **25**, such as the

sleeve **27** or structural member. The sections **41***a*, **41***b* are radially aligned to pair and form a single acoustic vane **41**. In some examples, the inner lateral sides **44** abut together. In other examples, the inner lateral sides **44** are spaced apart by a gap. In some examples, the second sections **41***b* are mounted to a non-translating section of the sleeve **27**. In other examples, the second sections **41***b* are mounted to the sleeve **27** and translate with the sleeve **27**. During the translating movement, the second section **41***b* axially moves along the first section **41***a*. The shapes and sizes of the sections **41***a*, **41***b* can be the same or different. In some examples, the sections **41***a*, **41***b* include different lengths L.

(24) The acoustic vanes **41** can be located at different longitudinal positions along the fan duct **25** between the drag links **32** and the aft end of the nozzle exit **29**. In some examples, the aft end **43** of the acoustic vanes **41** are aligned with a plane formed by the nozzle exit **29**. In some examples as illustrated in FIG. **7**, the aft end **62** of the fan nacelle **24** includes chevrons **63**. In some examples as illustrated in FIG. **7**, the acoustic vanes **41** are attached to the sleeve **27** that forms the aft section of the fan nacelle **24**. In these examples, the acoustic vanes **41** translate with the movement of the sleeve **27**.

(25) The acoustic vanes **41** can include various shapes and sizes. FIG. **8** illustrates an example with the vane **41** having a curved shape between the inner and outer lateral sides **44**, **45**. FIG. **4** illustrates another example with the vane **41** being straight between the inner and outer lateral sides **44**, **45**.

(26) FIG. **9** illustrates a method of reducing noise produced by a fan **23** of an engine **20** of an aircraft **100**. The method includes mounting acoustic vanes **41** in a fan duct **25** of the engine **20** (block **200**). The acoustic vanes **41** are positioned aft of drag links **32** of a thrust reverser **30** and positioned in disturbed air caused by the drag links **32**. During operation of the engine **20**, the drag links **32** are positioned in a first position with blocker doors **31** in an open position to enable airflow through the fan duct **25** from an inlet **28** to an nozzle exit **29** (block **202**). The drag links **32** are positioned in a second position with the blocker doors **31** in a closed position to direct the airflow in the fan duct **25** away from the nozzle exit **29** (block **204**).

(27) One advantage of the acoustic attenuation system **40** is the ability to retrofit existing engines **20**. The retrofit can be accomplished without the need for a redesign of the airflow through the engine **20**. The acoustic attenuation system **40** can also be readily integrated into new engine designs.

(28) By the term "substantially" with reference to amounts or measurement values, it is meant that the recited characteristic, parameter, or value need not be achieved exactly. Rather, deviations or variations, including, for example, tolerances, measurement error, measurement accuracy limitations, and other factors known to those skilled in the art, may occur in amounts that do not preclude the effect that the characteristic was intended to provide.

(29) The present invention may, of course, be carried out in other ways than those specifically set forth herein without departing from essential characteristics of the invention. The present embodiments are to be considered in all respects as illustrative and not restrictive, and all changes coming within the meaning and equivalency range of the appended claims are intended to be embraced therein.

Claims

1. An engine of an aircraft comprising: a fan; an engine core that produces thrust to propel the aircraft; a fan duct positioned downstream from the fan and that extends along a length of the engine core and is positioned between an engine core nacelle inner wall and a fan nacelle, the fan duct comprising an inlet and a nozzle exit; a thrust reverser positioned along the fan duct and comprising a plurality of blocker doors and drag links, the thrust reverser positionable between an open position and a closed position, the open position locates the blocker doors for the air to move

along the fan duct and exit at the nozzle exit, the closed position locates the blocker doors across the fan duct to direct the air out of the fan duct through an opening in the fan nacelle; an acoustic attenuation system comprising acoustic vanes mounted in the fan duct and positioned between the thrust reverser and the nozzle exit and aft of the drag links with each one of the acoustic vanes aligned behind a respective one of the drag links, the acoustic attenuation system configured to reduce fan blade-pass frequency noise caused by the fan; and wherein the acoustic vanes comprise: a first section mounted to and extending outward into the fan duct from a first side wall of the fan duct; a second section mounted to and extending outward from a second side wall of the fan duct; and the first section and the second section aligned on opposing sides of the fan duct and comprising inner lateral sides that face together.

2. The engine of claim 1, wherein the acoustic vanes are aligned in the fan duct around the engine core nacelle inner wall and connected to a wall of the fan duct.

3. The engine of claim 1, wherein the acoustic vanes comprise a forward end that is tapered, an opposing aft end, an inner lateral side, and an outer lateral side with the outer lateral side mounted to a wall of the fan duct.

4. The engine of claim 3, wherein the forward end of each of the acoustic vanes is aligned with one of the drag links for the acoustic vanes to be positioned in the fan duct in disturbed air flow.

5. The engine of claim 3, wherein the inner lateral sides of the acoustic vanes are exposed within the fan duct.

6. The engine of claim 1, wherein the acoustic vanes comprise a forward end and an aft end with the aft ends aligned with a plane aligned at the nozzle exit.

7. The engine of claim 1, wherein the fan nacelle comprises a forward section that is fixed and an aft section that translates along the fan duct with the second section of the acoustic vanes mounted to the aft section.

8. The engine of claim 1, wherein the acoustic vanes comprise a forward end, an opposing aft end, an inner lateral side, and an outer lateral side, the acoustic vanes comprising a shape that is curved between the inner lateral side and the outer lateral side.

9. The engine of claim 1, wherein the fan nacelle comprises chevrons at the nozzle exit and the acoustic vanes are aligned with the chevrons along the fan nacelle.

10. The engine of claim 1, wherein the acoustic vanes comprise different thicknesses.

11. An engine of an aircraft comprising: a fan; an engine core configured to produce thrust to propel the aircraft; a fan duct that extends along the engine core downstream from the fan; blocker doors mounted in the fan duct; drag links mounted in the fan duct, each one of the drag links connected to one of the blocker doors, the drag links configured to move the blocker doors between an open position to direct airflow along the fan duct and a closed position to direct air out of the fan duct; acoustic vanes mounted in the fan duct aft of the drag links, each of the acoustic vanes aligned with one of the drag links to be positioned in disturbed air caused by the respective one of the drag links; and wherein the acoustic vanes comprise: a first section mounted to and extending outward into the fan duct from a first side wall of the fan duct; a second section mounted to and extending outward from a second side wall of the fan duct; and the first section and the second section aligned on opposing sides of the fan duct and comprising inner lateral sides that face together.

12. The engine of claim 11, wherein the acoustic vanes comprise a forward end and a trailing end, the acoustic vanes positioned in the fan duct with the forward ends aligned with the drag links.

13. The engine of claim 11, wherein the acoustic vanes comprise a flat shape with an inner lateral side that is straight, the inner lateral sides aligned with the drag links.

14. The engine of claim 11, further comprising a fan nacelle with a forward section that is fixed relative to the fan duct and an aft section that translates relative to the fan duct with the second section of the acoustic vanes mounted on the aft section of the fan nacelle.

15. The engine of claim 14, wherein the fan nacelle comprises chevrons at the aft section.

16. The engine of claim 11, wherein the inner lateral sides of the first section and the second section abut together.
17. The engine of claim 11, wherein the acoustic vanes comprise different thicknesses.
18. A method of reducing noise of an engine of an aircraft, the method comprising: mounting acoustic vanes in a fan duct of the engine with the acoustic vanes positioned aft of and aligned behind drag links of a reverse thruster and positioned in disturbed air caused by the drag links; positioning the drag links in a first position and positioning blocker doors in an open position to enable airflow through the fan duct from an inlet to a nozzle exit; positioning the drag links in a second position and positioning the blocker doors in a closed position to direct the airflow in the fan duct away from the nozzle exit; and wherein each of the acoustic vanes comprises an inner section and an outer section and further comprising translating the outer section relative to the inner section when moving the drag links from the first position to the second position.
19. The method of claim 18, further comprising translating the acoustic vanes along the fan duct while moving the drag links from the first position to the second position.
20. The method of claim 18, further comprising maintaining the inner sections of the acoustic vanes in fixed positions while translating the outer sections.