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Vertical Takeoff and Landing Aircraft

Abstract

A vertical takeoff and landing (VTOL) aircraft includes a maximum takeoff weight (MTOW) of about 1700-kg, a cruising speed of about 80-knots equivalent airspeed (EAS) to about 100-knots EAS, a nominal range of about 300-km, a nominal flight time of about 4-hours, and at least one pair of rotors configured to provide vertical thrust. Each rotor of the at least one pair includes an about 2-meter propeller diameter, a disk loading of about 67-kg/m.² to about 110-kg/m.², and an operating speed of about 1800 rotations-per-minute (RPM) to about 2700-RPM.

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Background/Summary

BACKGROUND

1. Field

[0001] Embodiments of the invention relate generally to vertical takeoff and landing (VTOL) aircraft, and more specifically to a mid-range aircraft for transporting cargo with electrically powered takeoff and landing and combustion engine powered forward propulsion.

2. Description of the Related Art

[0002] Many types of VTOL electric aircraft are known. U.S. Pat. No. 10,035,587 to Bevirt et al. describes a VTOL tri-rotor aircraft with two rotors mounted on forward wing tips, and the three rotors may be powered by electric motors. U.S. Pat. No. 10,974,827 to Bevirt et al. describes a tri-rotor VTOL aircraft, and the rotors may be powered by electric motors. U.S. Pat. No. 10,071,801 to North et al. describes a tri-rotor VTOL aircraft, and the three rotors may be powered by electric motors. U.S. Pat. No. 10,676,188 to Campbell et al. describes a tilt-rotor aircraft with two forward rotors and one aft rotor, and the three rotors may be powered by electric motors.

SUMMARY

[0003] This summary is provided to introduce a selection of concepts in a simplified form that are further described below in the detailed description. This summary is not intended to identify key features or essential features of the claimed subject matter, nor is it intended to be used to limit the scope of the claimed subject matter. Other aspects and advantages of the invention will be apparent from the following detailed description of the embodiments and the accompanying drawing figures.

[0004] In an embodiment, a vertical takeoff and landing (VTOL) aircraft includes a maximum takeoff weight (MTOW) of about 1700-kg, a cruising speed of about 80-knots equivalent airspeed (EAS) to about 100-knots EAS, a nominal range of about 300-km, a nominal flight time of about 4-hours, and at least one pair of rotors configured to provide vertical thrust. Each rotor of the at least one pair includes an about 2-meter propeller diameter, a disk loading of about 67-kg/m.² to about 110-kg/m.², and an operating speed of about 1800 rotations-per-minute (RPM) to about 2700-RPM.

[0005] In an embodiment, a method of operating a vertical takeoff and landing (VTOL) aircraft includes: providing vertical thrust during lift off with at least one pair of rotors, including: rotating the at least one pair of rotors at a speed of about 1800 rotations-per-minute (RPM) to about 2700-RPM, and operating the at least one pair of rotors with a disk loading of about 67-kg/m.² to about 110-kg/m.². The method further includes lifting off with a takeoff weight less than a maximum takeoff weight (MTOW) of about 1700-kg, and cruising with a speed of about 80-knots equivalent airspeed (EAS) to about 100-knots EAS.

Description

BRIEF DESCRIPTION OF THE DRAWING FIGURES

[0006] Embodiments of the invention are described in detail below with reference to the attached drawing figures, wherein:

[0007] FIG. 1 is a perspective view of an embodiment of a VTOL aircraft;

[0008] FIG. 2 is another perspective view of the VTOL aircraft of FIG. 1;

[0009] FIG. 3 is a rear perspective view of the VTOL aircraft of FIG. 1;

[0010] FIG. 4 is a first side view of the VTOL aircraft of FIG. 1;

[0011] FIG. 5 is a second side view opposite the first side of the VTOL aircraft of FIG. 1; and

[0012] FIG. 6 is a front view of the VTOL aircraft of FIG. 1.

[0013] The drawing figures do not limit the invention to the specific embodiments disclosed and described herein. The drawings are not necessarily to scale, emphasis instead being placed upon clearly illustrating the principles of the invention.

DETAILED DESCRIPTION

[0014] The following detailed description references the accompanying drawings that illustrate specific embodiments in which the invention can be practiced. The embodiments are intended to describe aspects of the invention in sufficient detail to enable those skilled in the art to practice the invention. Other embodiments can be utilized, and changes can be made without departing from the scope of the invention. The following detailed description is, therefore, not to be taken in a limiting sense. The scope of the invention is defined only by the appended claims, along with the full scope of the equivalents to which such claims are entitled.

[0015] In this description, references to “one embodiment,” “an embodiment,” or “embodiments” mean that the feature or features being referred to are included in at least one embodiment of the technology. Separate references to “one embodiment,” “an embodiment,” or “embodiments” in this description do not necessarily refer to the same embodiment and are also not mutually exclusive unless so stated and/or except as will be readily apparent to those skilled in the art from the description. For example, a feature, structure, act, etc. described in one embodiment may also be included in other embodiments, but is not necessarily included. Thus, the technology can include a variety of combinations and/or integrations of the embodiments described herein.

[0016] FIGS. **1-6** provide various views of a VTOL aircraft **100**. Aircraft **100** has vertical takeoff and landing capabilities that are powered by electrically driven rotors **160**. During forward flight, the aircraft is propelled by a pusher propeller **170** that is powered by a combustion engine, and the rotors **160** may be locked while not being used during forward flight. FIGS. **1-6** are best viewed together with the following description.

[0017] A fuselage **110** is aligned lengthwise in a longitudinal direction. A nose cone **112** covers a forward end of the fuselage **110**. In embodiments, nose cone **112** is configured as a door that swings open/closed for enabling loading/unloading of cargo. A housing **115** is shown disposed on a top side of the fuselage **110**; however, housing **115** may alternatively be disposed on an underside of the fuselage **110** without departing from the scope hereof. Housing **115** may be configured to house antenna (e.g., one or more GPS antennas) and affiliated equipment.

[0018] A forward wing **122** extends in a lateral direction from both sides of the fuselage. As shown in FIGS. **1-6**, forward wing **122** is configured as a lower wing across or below a lower portion of the fuselage. Forward wing **122** comprises a slight taper with the leading edge being slightly swept and the trailing edge being unswept (i.e., straight) such that forward wing **122** is narrower at an outboard tip of the wing compared to an inboard portion adjacent the fuselage **110**. As best viewed in FIG. **6**, forward wing **122** lacks any dihedral angle either upwards or downwards (i.e., forward wing **122** when unloaded extends substantially horizontally from the fuselage **110**). In embodiments, forward wing **122** is configured to provide a wing loading of about 44-kg/m.^{sup.2} to about 68-kg/m.^{sup.2} during level-steady flight.

[0019] An aft wing **124** extends in a lateral direction from both sides of the fuselage. As shown in FIGS. **1-6**, aft wing **124** is configured as an upper wing across or above an upper portion of the fuselage. The leading edge of aft wing **124** comprises a curvature that provides a slight sweep and taper, while the trailing edge is unswept (i.e., straight), such that aft wing **124** is narrower at an outboard tip of the wing compared to an inboard portion adjacent the fuselage **110**. As best viewed in FIG. **6**, aft wing **124** lacks any dihedral angle either upwards or downwards (i.e., aft wing **124** when unloaded extends substantially horizontally from the fuselage **110**). In embodiments, aft wing **124** is configured to provide a wing loading of about 48-kg/m.^{sup.2} to about 70-kg/m.^{sup.2} during level-steady flight. In certain embodiments, aft wing **124** provides a wing loading of about 59.1 kg/m.^{sup.2}.

[0020] A right longitudinal boom **131** extends longitudinally on the right side of the aircraft **100** and a left longitudinal boom **133** extends longitudinally on the left side. The longitudinal booms **131**, **133** are disposed beneath the forward wing **122** and outboard of the fuselage **110**. A right tail **141** extends substantially vertically from right longitudinal boom **131** to aft wing **124**. A right rudder **145** is supported by and operatively coupled to the right tail **141**. Similarly on the opposite

side, a left tail **143** extends substantially vertically from left longitudinal boom **133** to aft wing **124**, and a left rudder **147** is supported by and operatively coupled to the left tail **143** (see FIGS. 3 and 4). Right rudder **145** and left rudder **147** are configured to provide directional control of aircraft **100**. In embodiments, additional rudder surfaces may be provided for directional control without departing from the scope hereof. The left and right longitudinal booms **131**, **133** extend forward of forward wing **122** to aft wing **124** in the longitudinal direction (see FIG. 3).

[0021] A right aft boom **151** extends aft of the aft wing **124** in the longitudinal direction on the right side of the aircraft **100**. A right aft tail stabilizer **155** forms the tail end of right aft boom **151** and extends upwards above the right aft boom **151**. Similarly, a left aft boom **153** extends aft of the aft wing **124** in the longitudinal direction on the left side of the aircraft **100**. A left aft tail stabilizer **157** forms the tail end of left aft boom **153** and extends upwards above the left aft boom **153**.

[0022] In embodiments, right longitudinal boom **131**, right tail **141**, right aft boom **151**, and right aft tail stabilizer **155** are constructed as a single member. Similarly, left longitudinal boom **133**, left tail **143**, left aft boom **153**, and left aft tail stabilizer **157** may be constructed as a single member.

[0023] In embodiments, aircraft **100** includes eight electrically driven rotors **160** arranged in four left-right pairs. However, fewer or greater than eight rotors **160** may be employed on aircraft **100** without departing from the scope hereof. As shown in FIGS. 1-6, three of the left-right pairs of rotors **160** are disposed on a top side of the longitudinal booms **131**, **133** and a fourth left-right pair of rotors **160** is disposed on the top side of the aft booms **151**, **153**. A first pair of the three pairs of rotors **160** is disposed forward of the forward wing, and a second pair and a third pair of the three pairs are disposed between the forward wing **122** and the aft wing **124**. The rotors **160** face substantially upright (i.e., substantially vertically facing) to provide vertical thrust for takeoff and landing maneuvers. However, each of the rotors **160** may be tilted slightly left or right from vertical to assist with yaw control. In embodiments, the slight left/right tilt is fixed. Other arrangements of the rotors **160** on the booms of aircraft **100** may be employed without departing from the scope hereof.

[0024] Each rotor **160** includes an electric motor. In embodiments, electrical energy may be provided to the electric motors via one or more batteries, turbogenerators (e.g., one or more of a turbine, diesel, or gas engine configured to drive electrical generators), or a hydrogen fuel cell, for example. The rotors **160** are configured as fixed orientation rotors (i.e., the rotors are not tiltable) for remaining in the upright (i.e., vertically facing) position.

[0025] In certain embodiments, rotors **160** may have a propeller diameter of about 2-meters and a disk loading of about 67-kg/m² to about 110-kg/m². In some embodiments, aircraft **100** operates with only six of eight rotors **160** functioning at a time with a disk loading of at least about 90-kg/m². Additionally, rotors **160** may be configured to operate at about 1800 rotations-per-minute (RPM) to about 2700-RPM in embodiments, depending on power requirements and atmospheric conditions.

[0026] Pusher propeller **170** is located on an aft end of the fuselage **110**. In embodiments, the pusher propeller **170** is powered by a combustion engine (e.g., a gas-powered engine) and is configured for pushing the aircraft **100** forward primarily during the cruise phase of flight. Alternatively, pusher propeller **170** is powered by a direct-drive turboprop or turboelectric engine (e.g., a turbine/generator/electric motor combination) or a hydrogen fuel cell. In certain embodiments, pusher propeller **170** has a propeller diameter of about 2-meters.

[0027] In embodiments, rotors **160** are each equipped with a locking mechanism configured for locking the rotors **160** to prevent them from spinning during forward flight (e.g., during the cruise phase of flight) when pusher propeller **170** is providing forward power. In embodiments, each locking mechanism is configured to lock each respective rotor in one of two positions such that the propeller blades are aligned in the longitudinal direction while locked in a stationary position. The rotors **160** are maintained in a stationary position via the locking mechanism during at least a portion of the cruise phase of flight. An exemplary locking mechanism for use with rotors **160** is

described in co-pending U.S. patent application Ser. No. 18/531,624, entitled "Propeller Locking Mechanism," and filed Dec. 6, 2023, the disclosure of which is herein incorporated by reference in its entirety.

[0028] A plurality of shock absorbing pegs **180** are disposed on lower side of right and left longitudinal booms **131**, **133**. The pegs **180** are provided in lieu of wheels and are configured for supporting the aircraft **100** on the ground and each include one or more shock absorbers or oleo struts for helping to control landing of the aircraft **100** by absorbing impact during vertical landing maneuvers. In embodiments, each of the right and left longitudinal booms **131**, **133** comprises a pair of shock absorbing pegs **180**. In certain embodiments, an aerodynamic fairing is provided to cover each of the pegs **180** for reducing drag during the cruise phase of flight.

[0029] A ventral fin **190** is disposed on a bottom side of the fuselage **110** at an aft end of the fuselage. Ventral fin **190** is configured to assist with directional stability. In embodiments, ventral fin **190** is fixed and comprises a substantially flat surface.

[0030] A plurality of control surfaces may be disposed on the forward wing **122** and aft wing **124**. For example, a forward-right control surface **191** and a forward-left control surface **192** are provided on the trailing edge of forward wing **122**; similarly, an aft-right control surface **193** and an aft-left control surface **194** are provided on the trailing edge of aft wing **124**. The control surfaces **191-194** are configured to operate in conjunction for controlling pitch and roll of aircraft **100**. In embodiments, if any one of the control surfaces **191-194** is jammed in any normally encountered position, the three remaining control surfaces may be trimmed to maintain pitch and roll control of aircraft **100**.

[0031] In embodiments, aircraft **100** is configured to provide a maximum takeoff weight (MTOW) of about 1700-kg, a cruising speed of about 80-knots equivalent airspeed (EAS) to about 100-knots EAS, a nominal range of about 300-km and a maximum range of up to 1500-km. For a 300-km flight, the nominal flight time is about 4-hours and for the maximum range the flight time is about 9-hours. The longer flight time may be achieved by installing additional fuel tanks in the cargo bay, trading payload capacity for additional fuel to provide increased range.

[0032] Features described above as well as those claimed below may be combined in various ways without departing from the scope hereof. The following clauses illustrate some possible, non-limiting combinations:

[0033] Clause 1. A vertical takeoff and landing (VTOL) aircraft, comprising: a maximum takeoff weight (MTOW) of about 1700-kg; a cruising speed of about 80-knots equivalent airspeed (EAS) to about 100-knots EAS; a nominal range of about 300-km; a nominal flight time of about 4-hours; and at least one pair of rotors configured to provide vertical thrust, wherein each rotor of the at least one pair comprises: a about 2-meter propeller diameter; a disk loading of about 67-kg/m.sup.2 to about 110-kg/m.sup.2; and an operating speed of about 1800 rotations-per-minute (RPM) to about 2700-RPM.

[0034] Clause 2. The VTOL aircraft of clause 1 comprising a forward wing configured to provide a wing loading of about 44-kg/m.sup.2 to about 68-kg/m.sup.2 during level-steady flight.

[0035] Clause 3. The VTOL aircraft of clause 1 comprising an aft wing configured to provide a wing loading of about 48-kg/m.sup.2 to about 70-kg/m.sup.2 during level-steady flight.

[0036] Clause 4. The VTOL aircraft of clause 1 comprising a maximum range of up to about 1500-km.

[0037] Clause 5. The VTOL aircraft of clause 1 comprising a maximum flight time of up to about 9-hours.

[0038] Clause 6. The VTOL aircraft of clause 1, wherein a disk loading is at least about 90-kg/m.sup.2 when six rotors are functioning at a time.

[0039] Clause 7. The VTOL aircraft of clause 1, wherein the at least one pair of rotors each comprise an electric motor.

[0040] Clause 8. The VTOL aircraft of clause 1 comprising a pusher propeller, wherein the pusher

propeller has a propeller diameter of about 2-meters.

[0041] Clause 9. A method of operating a vertical takeoff and landing (VTOL) aircraft, comprising: providing vertical thrust during lift off with at least one pair of rotors, comprising: rotating the at least one pair of rotors at a speed of about 1800 rotations-per-minute (RPM) to about 2700-RPM; and operating the at least one pair of rotors with a disk loading of about 67-kg/m.² to about 110-kg/m.²; lifting off with a takeoff weight less than a maximum takeoff weight (MTOW) of about 1700-kg; and cruising with a speed of about 80-knots equivalent airspeed (EAS) to about 100-knots EAS.

[0042] Clause 10. The method of clause 9 comprising cruising with a forward wing loading of about 44-kg/m.² to about 68-kg/m.².

[0043] Clause 11. The method of clause 9 comprising cruising with an aft wing loading of about 48-kg/m.² to about 70-kg/m.².

[0044] Clause 12. The method of clause 9 comprising operating three pairs of rotors with a disk loading of at least about 90-kg/m.².

[0045] Clause 13. The method of clause 9, wherein cruising comprises propelling forward using a pusher propeller.

[0046] Clause 14. The method of clause 13 comprising powering the pusher propeller via a combustion engine.

[0047] Clause 15. The method of clause 9 comprising landing on the ground vertically during a landing phase of flight via the at least one pair of rotors.

[0048] Although the invention has been described with reference to the embodiments illustrated in the attached drawing figures, it is noted that equivalents may be employed and substitutions made herein without departing from the scope of the invention as recited in the claims.

[0049] Having thus described various embodiments of the invention, what is claimed as new and desired to be protected by Letters Patent includes the following:

Claims

1. A vertical takeoff and landing (VTOL) aircraft, comprising: a maximum takeoff weight (MTOW) of about 1700-kg; a cruising speed of about 80-knots equivalent airspeed (EAS) to about 100-knots EAS; a nominal range of about 300-km; a nominal flight time of about 4-hours; and at least one pair of rotors configured to provide vertical thrust, wherein each rotor of the at least one pair comprises: an about 2-meter propeller diameter; a disk loading of about 67-kg/m.² to about 110-kg/m.²; and an operating speed of about 1800 rotations-per-minute (RPM) to about 2700-RPM.

2. The VTOL aircraft of claim 1 comprising a forward wing configured to provide a wing loading of about 44-kg/m.² to about 68-kg/m.² during level-steady flight.

3. The VTOL aircraft of claim 1 comprising an aft wing configured to provide a wing loading of about 48-kg/m.² to about 70-kg/m.² during level-steady flight.

4. The VTOL aircraft of claim 1 comprising a maximum range of up to about 1500-km.

5. The VTOL aircraft of claim 1 comprising a maximum flight time of up to about 9-hours.

6. The VTOL aircraft of claim 1, wherein a disk loading is at least about 90-kg/m.² when six rotors are functioning at a time.

7. The VTOL aircraft of claim 1, wherein the at least one pair of rotors each comprise an electric motor.

8. The VTOL aircraft of claim 1 comprising a pusher propeller, wherein the pusher propeller has a propeller diameter of about 2-meters.

9. A method of operating a vertical takeoff and landing (VTOL) aircraft, comprising: providing vertical thrust during lift off with at least one pair of rotors, comprising: rotating the at least one pair of rotors at a speed of about 1800 rotations-per-minute (RPM) to about 2700-RPM; and

operating the at least one pair of rotors with a disk loading of about 67-kg/m.sup.2 to about 110-kg/m.sup.2; lifting off with a takeoff weight less than a maximum takeoff weight (MTOW) of about 1700-kg; and cruising with a speed of about 80-knots equivalent airspeed (EAS) to about 100-knots EAS.

10. The method of claim 9 comprising cruising with a forward wing loading of about 44-kg/m.sup.2 to about 68-kg/m.sup.2.

11. The method of claim 9 comprising cruising with an aft wing loading of about 48-kg/m.sup.2 to about 70-kg/m.sup.2.

12. The method of claim 9 comprising operating three pairs of rotors with a disk loading of at least about 90-kg/m.sup.2.

13. The method of claim 9, wherein cruising comprises propelling forward using a pusher propeller.

14. The method of claim 13 comprising powering the pusher propeller via a combustion engine.

15. The method of claim 9 comprising landing on the ground vertically during a landing phase of flight via the at least one pair of rotors.
