# FOLDING CONCENTRICALLY MOUNTED PROPELLER BLADES FOR DRAG REDUCTION

## TECHNICAL FIELD

**[0001]** This disclosure relates generally to propeller blade mounts, and in particular but not exclusively, relates to propeller blade mounts for unmanned aerial vehicles.

## BACKGROUND INFORMATION

**[0002]** An unmanned vehicle, which may also be referred to as an autonomous vehicle, is a vehicle capable of travel without a physically-present human operator. An unmanned vehicle may operate in a remote-control mode, in an autonomous mode, or in a partially autonomous mode.

**[0003]** When an unmanned vehicle operates in a remote-control mode, a pilot or driver that is at a remote location can control the unmanned vehicle via commands that are sent to the unmanned vehicle via a wireless link. When the unmanned vehicle operates in autonomous mode, the unmanned vehicle typically moves based on pre-programmed navigation waypoints, dynamic automation systems, or a combination of these. Further, some unmanned vehicles can operate in both a remote-control mode and an autonomous mode, and in some instances may do so simultaneously. For instance, a remote pilot or driver may wish to leave navigation to an autonomous system while manually performing another task, such as operating a mechanical system for picking up objects, as an example.

**[0004]** Various types of unmanned vehicles exist for various different environments. For instance, unmanned vehicles exist for operation in the air, on the ground, underwater, and in space. Unmanned aerial vehicles (UAVs) or drones are becoming more popular in general. As their designs are refined and their capabilities expanded, their suitability for commercial use is expected to expand. Designs that improve the efficiency and endurance of UAVs will expand their mission capabilities.

## SUMMARY OF INVENTION

[0005a] According to a first aspect of the present invention, there is provided a propulsion unit, comprising:

a motor rotor that spins about a central rotational axis;

propeller blades, including first and second propeller blades, each having a proximal base mounted to the motor rotor such that the propeller blades are rotatable about the central rotational axis, wherein the second propeller blade is pivotally attached to the motor rotor to pivot about the central rotational axis independent of the motor rotor by a limited angle;

a pivot stop to mechanically limit an amount of pivoting of the second propeller blade relative to the first propeller blade; and

a washer flange disposed between the proximal bases of the first and second propeller blades to offset the second propeller blade relative to the first propeller blade along the center rotational axis.

[0005b] According to a second aspect of the present invention, there is provided a propulsion unit, comprising:

a motor rotor that spins about a central rotational axis;

propeller blades, including first, second, and third propeller blades, each having a proximal base mounted to the motor rotor such that the propeller blades are rotatable about the central rotational axis, wherein the second propeller blade is pivotally attached to the motor rotor to pivot about the central rotational axis independent of the motor rotor by a limited angle;

a pivot stop to mechanically limit an amount of pivoting of the second propeller blade relative to the first propeller blade; and

a second pivot stop integrated onto a second washer flange disposed to offset the proximal bases of the second and third propeller blades.

[0005c] According to a third aspect of the present invention, there is provided an aerial vehicle, comprising:

an airframe;

a horizontal propulsion unit mounted to the airframe and oriented to provide horizontal propulsion to the aerial vehicle; and

a vertical propulsion unit mounted to the airframe and oriented to provide vertical propulsion to the aerial vehicle, the vertical propulsion unit including:

a motor rotor that spins about a central rotational axis;

propeller blades, including first and second propeller blades, each having a proximal base mounted to the motor rotor such that the propeller blades are rotatable about the central rotational axis, wherein the second propeller blade is pivotally attached to the motor rotor to pivot about the central rotational axis independent of the motor rotor by a limited angle;

a pivot stop disposed relative to the first and second propeller blades to mechanically limit an amount of pivoting of the second propeller blade relative to the first propeller blade; and

a washer flange disposed between the proximal bases of the first and second propeller blades to offset the second propeller blade relative to the first propeller blade along the center rotational axis.

[0005d] According to a fourth aspect of the present invention, there is provided an aerial vehicle, comprising:

an airframe;

a horizontal propulsion unit mounted to the airframe and oriented to provide horizontal propulsion to the aerial vehicle; and

a vertical propulsion unit mounted to the airframe and oriented to provide vertical propulsion to the aerial vehicle, the vertical propulsion unit including:

a motor rotor that spins about a central rotational axis;

propeller blades, including first and second propeller blades, each having a proximal base mounted to the motor rotor such that the propeller blades are rotatable about the central rotational axis, wherein

the second propeller blade is pivotally attached to the motor rotor to pivot about the central rotational axis independent of the motor rotor by a limited angle; and

a pivot stop disposed relative to the first and second propeller blades to mechanically limit an amount of pivoting of the second propeller blade relative to the first propeller blade,

wherein the propeller blades of the vertical propulsion unit fold or unfold between a deployed position that provides the vertical propulsion and a stowed position having a reduced drag profile during a forward motion of the aerial vehicle,

wherein the vertical propulsion unit is adapted to apply a reverse torque impulse to initiate folding of the propeller blades to the stowed position.

[0005e] According to a first aspect of the present invention, there is provided a propulsion unit, comprising:

a motor rotor that spins about a central rotational axis;

propeller blades, including first and second propeller blades, each having a proximal base mounted to the motor rotor such that the propeller blades are rotatable about the central rotational axis, wherein the second propeller blade is pivotally attached to the motor rotor to pivot about the central rotational axis independent of the motor rotor by a limited angle; and

a pivot stop configured to mechanically limit an amount of pivoting of the second propeller blade relative to the first propeller blade by engaging cutouts in the proximal bases of the first and second propeller blades.

## BRIEF DESCRIPTION OF THE DRAWINGS

**[0005]** Non-limiting and non-exhaustive embodiments of the invention are described with reference to the following figures, wherein like reference numerals refer to

CLAIMS

1. A propulsion unit, comprising:

a motor rotor that spins about a central rotational axis;

propeller blades, including first and second propeller blades, each having a proximal base mounted to the motor rotor such that the propeller blades are rotatable about the central rotational axis, wherein the second propeller blade is pivotally attached to the motor rotor to pivot about the central rotational axis independent of the motor rotor by a limited angle;

a pivot stop to mechanically limit an amount of pivoting of the second propeller blade relative to the first propeller blade; and

a washer flange disposed between the proximal bases of the first and second propeller blades to offset the second propeller blade relative to the first propeller blade along the center rotational axis.

2. The propulsion unit of claim 1, wherein the propeller blades fold or unfold between a deployed position that provides propulsion and a stowed position having a reduced drag profile in a direction that is orthogonal to the central rotational axis.

3. The propulsion unit of claim 1, wherein the first propeller blade is non-pivotally attached to the motor rotor to rotate about the central rotational axis in a fixed relation to the motor rotor.

4. The propulsion unit of claim 1, wherein the pivot stop comprises a pair of rotationally offset protrusions extending from opposite sides of the washer flange that engage cutouts in the proximal bases of the first and second propeller blades.

5. The propulsion unit of claim 1, further comprising:

an alignment boss attached to and extending from the washer flange about which a hole in the proximal base of the second propeller blade is located.

6. The propulsion unit of claim 5, wherein the washer flange includes a recess that mates to and aligns with a protruding ridge on the motor rotor.

7. The propulsion unit of claim 5, further comprising:

a retainer cap for clamping the propeller blades and the washer flange to the motor rotor; and

a mechanical fastener that inserts through holes in the retainer cap and the alignment boss to thread into the motor rotor.

8. A propulsion unit, comprising:

a motor rotor that spins about a central rotational axis;

propeller blades, including first, second, and third propeller blades, each having a proximal base mounted to the motor rotor such that the propeller blades are rotatable about the central rotational axis, wherein the second propeller blade is pivotally attached to the motor rotor to pivot about the central rotational axis independent of the motor rotor by a limited angle;

a pivot stop to mechanically limit an amount of pivoting of the second propeller blade relative to the first propeller blade; and

a second pivot stop integrated onto a second washer flange disposed to offset the proximal bases of the second and third propeller blades.

9. The propulsion unit of claim 8, wherein the pivot stop and the second pivot stop offset rotational positions of the propeller blades relative to each other by equal angles when the propeller blades are unfolded to a deployed position.

10. The propulsion unit of claim 8, wherein the propeller blades further include a fourth propeller blade, the propulsion unit further comprises:

a third pivot stop integrated onto a third washer flange disposed between the proximal bases of the third and fourth propeller blades.

11. An aerial vehicle, comprising:

an airframe;

a horizontal propulsion unit mounted to the airframe and oriented to provide horizontal propulsion to the aerial vehicle; and

a vertical propulsion unit mounted to the airframe and oriented to provide vertical propulsion to the aerial vehicle, the vertical propulsion unit including:

a motor rotor that spins about a central rotational axis;

propeller blades, including first and second propeller blades, each having a proximal base mounted to the motor rotor such that the propeller blades are rotatable about the central rotational axis, wherein the second propeller blade is pivotally attached to the motor rotor to pivot about the central rotational axis independent of the motor rotor by a limited angle;

a pivot stop disposed relative to the first and second propeller blades to mechanically limit an amount of pivoting of the second propeller blade relative to the first propeller blade; and

a washer flange disposed between the proximal bases of the first and second propeller blades to offset the second propeller blade relative to the first propeller blade along the center rotational axis.

12. The aerial vehicle of claim 11, wherein the propeller blades of the vertical propulsion unit fold or unfold between a deployed position that provides the

vertical propulsion and a stowed position having a reduced drag profile during a forward motion of the aerial vehicle.

13. The aerial vehicle of claim 12, wherein the propeller blades unfold to the deployed position by engaging the pivot stop between the first and second propeller blades when the motor rotor of the vertical propulsion unit is spinning and fold to the stowed position due to a wind resistance resulting from the forward motion of the aerial vehicle when the motor rotor of the vertical propulsion unit is not spinning.

14. The aerial vehicle of claim 12, wherein the vertical propulsion unit is adapted to apply a reverse torque impulse to initiate folding of the propeller blades to the stowed position.

15. The aerial vehicle of claim 11, wherein the first propeller blade is non-pivotally attached to the motor rotor to rotate about the central rotational axis in a fixed relation to the motor rotor.

16. The aerial vehicle of claim 11, wherein the pivot stop comprises a pair of rotationally offset protrusions extending from opposite sides of the washer flange that engage cutouts in the proximal bases of the first and second propeller blades.

17. The aerial vehicle of claim 11, further comprising:
an alignment boss attached to and extending from the washer flange about which a hole in the proximal base of the second propeller blade is located.

18. The aerial vehicle of claim 17, wherein the washer flange includes a recess that mates to and aligns with a protruding ridge on the motor rotor.

19. The aerial vehicle of claim 11, wherein the propeller blades further include a third propeller blade, the aerial vehicle further comprises:
a second pivot stop integrated onto a second washer flange disposed between the proximal bases of the second and third propeller blades.

20. The aerial vehicle of claim 19, wherein the pivot stop and the second pivot stop offset rotational positions of the propeller blades relative to each other by equal angles when the propeller blades are unfolded to a deployed position.

21. An aerial vehicle, comprising:

an airframe;

a horizontal propulsion unit mounted to the airframe and oriented to provide horizontal propulsion to the aerial vehicle; and

a vertical propulsion unit mounted to the airframe and oriented to provide vertical propulsion to the aerial vehicle, the vertical propulsion unit including:

a motor rotor that spins about a central rotational axis;

propeller blades, including first and second propeller blades, each having a proximal base mounted to the motor rotor such that the propeller blades are rotatable about the central rotational axis, wherein the second propeller blade is pivotally attached to the motor rotor to pivot about the central rotational axis independent of the motor rotor by a limited angle; and

a pivot stop disposed relative to the first and second propeller blades to mechanically limit an amount of pivoting of the second propeller blade relative to the first propeller blade,

wherein the propeller blades of the vertical propulsion unit fold or unfold between a deployed position that provides the vertical propulsion and a stowed position having a reduced drag profile during a forward motion of the aerial vehicle,

wherein the vertical propulsion unit is adapted to apply a reverse torque impulse to initiate folding of the propeller blades to the stowed position.

22. A propulsion unit, comprising:

a motor rotor that spins about a central rotational axis;

propeller blades, including first and second propeller blades, each having a proximal base mounted to the motor rotor such that the propeller blades are rotatable about the central rotational axis, wherein the second propeller blade is pivotally attached to the motor rotor to pivot about the central rotational axis independent of the motor rotor by a limited angle; and

a pivot stop configured to mechanically limit an amount of pivoting of the second propeller blade relative to the first propeller blade by engaging cutouts in the proximal bases of the first and second propeller blades.

23. The propulsion unit of claim 22, wherein the pivot stop comprises a pair of rotationally offset protrusions that engage the cutouts in the proximal bases of the first and second propeller blades.