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(54) **Title:** PITCH ATTITUDE CONTROL SYSTEM FOR INCREASING AIRCRAFT BRAKING EFFICIENCY

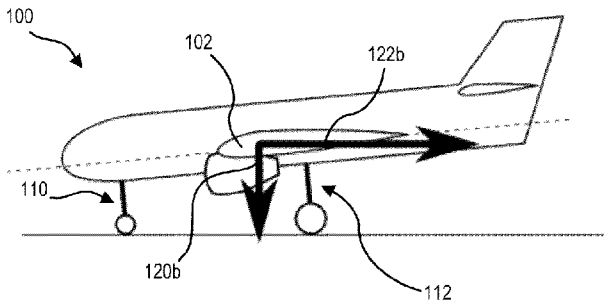


FIG. 1C

(57) **Abstract:** A system and method for controlling the pitch attitude of an aircraft is provided. The system can include a kneeling system operably coupled to a nose landing gear assembly and configured to position the wing of the aircraft in a negative angle of attack, thereby imparting a negative lift force on the aircraft. The kneeling system can be controlled by a pitch attitude controller configured to change the pressure in a pressure chamber of a kneeling cylinder in reaction to a kneeling signal of the aircraft. The signal can include information related to a required negative angle of attack of the wing based on the required braking force of the aircraft. The kneeling system can be used during rejected takeoff maneuvers to decrease stopping distance, thereby increasing the final point at which the rejected takeoff can be initiated, and can be used to decrease required runway length during landing.

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PITCH ATTITUDE CONTROL SYSTEM FOR INCREASING AIRCRAFT BRAKING EFFICIENCY

FIELD OF DISCLOSURE

The present disclosure relates to a pitch attitude control system for increasing aircraft braking efficiency. More particularly, the present disclosure relates to controlling the pitch attitude of an aircraft to create a negative wing angle of attack during aircraft maneuvers where increased braking efficiency is required.

BACKGROUND

Aircraft landing gear commonly utilize wheel brakes to slow and stop the aircraft during ground maneuvers and to assist other braking systems (thrust reversers, lift dump devices—ground and flight spoilers, etc.) to decelerate the aircraft after touch-down during landing or during a rejected takeoff. Typical wheel brakes employ friction materials to provide a resistive torque and to convert kinetic energy to heat. One limiting factor of the maximum braking force available by applying the wheel brakes is the friction between the tires and the runway. Generally, the wheel braking efficiency increases as weight of the aircraft increases based on increased normal force between the tires and the runway, thereby increasing the friction coefficient and the available braking force. Although lift dump devices work to reduce or eliminate the positive lift of the wings and the related decrease in normal force between the tires and the runway, certain aircraft maneuvers may still require additional braking force.

In some aircraft operating situations, an elevated aircraft energy level can affect safety maneuvers of the aircraft, e.g., the final rejected takeoff point, minimum runway length required for landing, etc. During takeoff, the final rejected takeoff point is the last point in time at which a decision can be made to abort the takeoff and safely slow the aircraft back down to taxiing speeds, which is based on the available braking force and runway length. In some situations, an elevated aircraft energy level as a result of increased takeoff weight and/or high velocity at a given runway length will move the rejected takeoff

point earlier than desired, and/or require that the aircraft avoid runways below a certain overall length. In other examples, it may be desirable to reduce the size of the brake system of the aircraft while maintaining the braking performance of a standard system. In these regards, it is desirable to selectively increase the braking efficiency of the aircraft when additional braking force is required, such as in situations of elevated aircraft energy levels, relatively short runways, and/or operating with a reduced braking system size.

SUMMARY

The present disclosure provides examples of increasing braking efficiency with a pitch attitude control system to induce a negative wing angle of attack in an aircraft. Embodiments of the present disclosure can include systems for controlling the pitch attitude of an aircraft while it is on the runway to create a negative wing angle of attack during aircraft maneuvers where increased braking efficiency is required. In some embodiments, the systems are configured to selectively create a negative pitch attitude (nose down) by shortening a nose landing gear of the aircraft, extending a main landing gear of the aircraft, or in other embodiments, extending the main landing gear assembly while shortening the nose landing gear.

In accordance with an aspect of the present disclosure, a pitch attitude control system for an aircraft is provided. The pitch attitude control system can include a nose landing gear assembly operably coupled to a body of the aircraft, the nose landing gear assembly having: a tire rotatable with respect to the nose landing gear assembly; and a kneeling system in communication with the pitch attitude control system and being positioned between the body and the tire, the kneeling system having a kneeling cylinder enclosing a pressure chamber and configured to selectively change the distance between the body and the tire such that a pitch attitude of the aircraft changes based on change in pressure within the pressure chamber. The pitch attitude control system can further include a pitch attitude controller configured to change the pressure in the pressure chamber of the kneeling cylinder in response to receiving a kneeling signal from an input device of the

aircraft, the kneeling signal containing information related to a required attack angle of a wing of the aircraft based on an input amplitude of the kneeling input device, the pitch attitude controller having at least one machine-accessible storage medium that provides instructions that, when executed by the pitch attitude controller, will cause the pitch attitude controller to perform operations, such as when a landing maneuver or a rejected takeoff maneuver is initiated by the aircraft, decrease the pressure in the pressure chamber to retract the kneeling system to a retracted position.

In accordance with another aspect of the present disclosure, a pitch attitude control system for an aircraft is provided. The pitch attitude control system can include a nose landing gear assembly operably coupled to a body of the aircraft, the nose landing gear assembly having a tire rotatable with respect to the nose landing gear assembly; and a deployment system in communication with the pitch attitude control system, the deployment system being positioned between the body and the tire and configured to transition the nose landing gear assembly between a stowed position and a deployed position. The pitch attitude control system can further include a pitch attitude controller configured to move the nose landing gear assembly with the deployment system in response to receiving a kneeling signal from an input device of the aircraft, the kneeling signal containing information related to a required attack angle of a wing of the aircraft based on an input amplitude of the kneeling input device, the pitch attitude controller having at least one machine-accessible storage medium that provides instructions that, when executed by the pitch attitude controller, will cause the pitch attitude controller to perform operations, such as when a landing maneuver or a rejected takeoff maneuver is initiated by the aircraft, transition the deployment system partially toward the stowed position to a retracted position.

In accordance with another aspect of the present disclosure, A method of changing a pitch attitude of an aircraft during a landing maneuver or a rejected takeoff maneuver, the aircraft having a kneeling system operably coupled to a nose landing gear assembly, the

kneeling system including a kneeling cylinder enclosing a pressure chamber and configured to selectively change the distance between a body of the aircraft and a tire such that the pitch attitude of the aircraft changes based on a change in pressure within the pressure chamber; and a pitch attitude controller in communication with the kneeling system is provided. The method can include determining a required negative angle of attack of a wing of the aircraft during a landing maneuver or a rejected takeoff maneuver based on the required braking force; receiving, by the pitch attitude controller, a kneeling signal from an input device of the aircraft; and reducing the pressure in the pressure chamber to retract the kneeling system to a retracted position based on an amplitude of the kneeling signal.

In any of the embodiments of the present disclosure, the pitch attitude control system can further provide instructions that, when executed by the pitch attitude controller, will cause the pitch attitude controller to perform operations, including after the landing maneuver or the rejected takeoff maneuver is completed, increase the pressure in the pressure chamber to extend the kneeling system to an extended position.

In any of the embodiments of the present disclosure, the nose landing gear assembly can further include a shock absorber positioned between the body and a tire of the nose landing gear assembly, the shock absorber configured to permit relative movement between the tire and the body.

In any of the embodiments of the present disclosure, the pressure chamber of the kneeling cylinder can be continuous with a pressure chamber of a shock absorber body.

In any of the embodiments of the present disclosure, the pressure chamber of the kneeling cylinder can be slidingly associated with a pressure chamber of a shock absorber body.

In any of the embodiments of the present disclosure, the attack angle of the wing can be negative when the kneeling system is in the retracted position and the tire is in contact with a ground surface, wherein a negative attack angle of the wing imparts a negative lift force on the aircraft during movement of the aircraft along the ground surface.

In any of the embodiments of the present disclosure, the aircraft can further include a main landing gear assembly having a friction brake; and a master brake and kneeling system controller in communication with the pitch attitude controller, the master brake and kneeling system controller configured to apply the friction brake in response to receiving a braking signal from an input device of the aircraft, the braking signal containing information related to a maximum braking force of the aircraft based in part on an amplitude of a negative lift force imparted on the aircraft when the kneeling system is in the retracted position and the attack angle of the wing is negative, the master brake and kneeling system controller having at least one machine-accessible storage medium that provides instructions that, when executed by the master brake and kneeling system controller, can cause the master brake and kneeling system controller to perform operations, such as applying the friction brake up to the maximum braking force.

In any of the embodiments of the present disclosure, the aircraft can further include a main landing gear assembly having a tire and a main landing gear extension system in communication with the pitch attitude controller and positioned between the body and the tire, the main landing gear extension system configured to extend the distance between the body and the tire to an extended position, wherein the attack angle of the wing can be negative when the main landing gear extension system is in the extended position.

In any of the embodiments of the present disclosure, the wing can have a greater negative angle of attach when the kneeling system in the retracted position and the main landing gear extension system is in extended position.

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 of the claimed subject matter, nor is it intended to be used as an aid in determining the scope of the claimed subject matter.

DESCRIPTION OF THE DRAWINGS

The foregoing aspects and many of the attendant advantages of the claimed subject matter will become more readily appreciated as the same become better understood by reference to the following detailed description, when taken in conjunction with the accompanying drawings, wherein:

FIGURE 1A depicts one example of an aircraft, such as a passenger or cargo aircraft, shown in side view and having a neutral pitch attitude, in which technologies and/or methodologies of the present disclosure may be employed;

FIGURE 1B is a side view of the aircraft of FIGURE 1A, showing the aircraft in takeoff and having a positive pitch attitude;

FIGURE 1C is a side view of the aircraft of FIGURE 1A, showing the aircraft kneeling and having a negative pitch attitude;

FIGURES 2A and 2B is a side view of a nose landing gear kneeling system in accordance with embodiments of the present disclosure;

FIGURE 3 is a functional block diagram of a braking and pitch attitude control system in accordance with aspects of the present disclosure, showing a kneeling system in the nose landing gear and friction braking in the main landing gear; and

FIGURE 4 is a flow chart illustrating a process for operating a pitch attitude control system of an aircraft in accordance with embodiments of the present disclosure.

DETAILED DESCRIPTION

The detailed description set forth above in connection with the appended drawings, where like numerals reference like elements, are intended as a description of various embodiments of the present disclosure and are not intended to represent the only embodiments. Each embodiment described in this disclosure is provided merely as an example or illustration and should not be construed as preferred or advantageous over other embodiments. The illustrative examples provided herein are not intended to be exhaustive or to limit the disclosure to the precise forms disclosed.

As will be described in more detail below, the present disclosure provides examples of systems for increasing the braking efficiency of an aircraft with a pitch attitude control system to induce a negative wing angle of attack in an aircraft. Embodiments of the present disclosure can include systems for controlling the pitch attitude of an aircraft while it is in contact with the runway to create a negative wing angle of attack during aircraft maneuvers where increased braking efficiency is required. In some embodiments, the systems are configured to selectively create a negative pitch attitude (nose down) by shortening a nose landing gear of the aircraft, extending a main landing gear of the aircraft, or in other embodiments, extending the main landing gear assembly while shortening the nose landing gear.

In embodiments described herein, the pitch attitude control system can include a kneeling system in the nose landing gear configured to shorten the distance between the aircraft body and the ground surface of a runway. The kneeling system can lower the nose of the aircraft relative to the tail to position the wings in a negative angle of attack relative to the direction of travel of the aircraft. When the wings have a negative angle of attack, the shape of the wings creates a negative lift (i.e., downforce) that increases the normal force between the tires and the ground surface of the runway, thereby increasing the friction coefficient and the available braking force. In aircraft operating situations where maximum braking force is required, the pitch attitude control system can position the wings in a negative angle of attack to increase the braking efficiency of the aircraft. This increase in braking efficiency can shorten the required braking distance during landing, move the final rejected takeoff point further down the runway, increase the speed at which a rejected takeoff can be initiated, reduce the required size of the brake system, among other advantages.

Although embodiments of the present disclosure may be described with reference to pitch attitude control systems that include a kneeling system in the nose landing gear of the aircraft, one skilled in the relevant art will appreciate that the disclosed embodiments

are illustrative in nature and therefore should not be construed as limited to such an application. It should therefore be apparent that the disclosed technologies and methodologies have wide application, and therefore may be employed by a length extending system of the main landing gear, or by a combination of the kneeling system in the nose landing gear and the length extending system in the main landing gear. Accordingly, the following descriptions and illustrations herein should not limit the scope of the claimed subject matter.

FIGURE 1A depicts one example of an aircraft 100, such as a passenger or cargo aircraft, shown in side view and having a neutral pitch attitude, in which technologies and/or methodologies of the present disclosure may be employed. The aircraft 100 can include a wing 102, a nose landing gear assembly 110 ("nose landing gear 110"), and a main landing gear assembly 112. In the configuration shown in FIGURE 1A, the wing 102 is configured to have a neutral or positive lift coefficient as the aircraft 100 travels along the runway. For purposes of the present disclosure, the wing 102 is shown without any flaps, spoilers, or slats deployed, which can affect the lift coefficient and drag of the wing 102. FIGURE 1B is a side view of the aircraft 100, showing the aircraft 100 during takeoff or landing and having a positive pitch attitude. In the configuration shown in FIGURE 1B, the wing 102 has a positive angle of attack and is configured to have a positive lift coefficient creating a positive lift force 120a as the aircraft 100 travels in the direction of the runway. FIGURE 1C is a side view of the aircraft 100, showing the aircraft 100 kneeling in accordance with embodiments of the present disclosure, such as during landing or a rejected takeoff, where the aircraft 100 has a negative pitch attitude. In the configuration shown in FIGURE 1C, the wing 102 has a negative angle of attack and is configured to have a negative lift coefficient creating a negative lift force 120b as the aircraft 100 travels in the direction of the runway. The negative lift force 120b is a downforce that increases the normal force between the tires and the ground surface of the

runway, thereby increasing the friction coefficient and the available braking force that can be applied without tire slip.

In all of the configurations shown in FIGURES 1A–1C, the wing 102 creates a drag force in a direction opposite to that of the direction of travel of the aircraft 100. In some configurations, the angle of attack of the wing 102 as shown in FIGURE 1A generally creates a minimum drag force, while changing the angle of attack of the wing 102 in a positive (FIGURE 1B) or negative (FIGURE 1C) direction increases the drag force, represented as a drag force 122a in FIGURE 1B and a drag force 122b in FIGURE 1C. Since the kneeled position with a negative pitch attitude shown in FIGURE 1C can be used in situations where maximum braking force is required, the drag force created by the wing 102 in a negative angle of attack works to assist the braking system in slowing down the aircraft 100, increasing the efficiency of the braking system. In the positive pitch attitude shown in FIGURE 1B, the engine thrust must overcome the drag to propel the aircraft 100 forward.

The landing gear assemblies 110 and 112 can include various components configured to support the body of the aircraft 100 above the ground surface, e.g., wheels, additional shock absorbers, brackets, hydraulics, sensors, actuators, controllers, etc., and such components are not shown for the sake of clarity in the FIGURES. It should be appreciated that the aircraft 100 illustrated in FIGURES 1A–1C should not be considered limiting on the present disclosure, and the landing gear systems can be arranged in various other configurations with fewer or additional components as desired. In addition, the particular location of the landing gear systems, the quantity of wheels and tires, and the other aspects of the aircraft 100 illustrated in FIGURES 1A–1C should not be considered limiting on the present disclosure, as the components may be positioned at various locations.

FIGURES 2A and 2B are side views of one example of a pitch attitude control system having a nose landing gear kneeling system 111 (“kneeling system 111”) of the

nose landing gear 110 of the aircraft 100 in accordance with embodiments of the present disclosure. The kneeling system 111 is an example of a system configured to position the aircraft 100 in the negative pitch attitude shown in FIGURE 1C to create a negative wing angle of attack and the negative downforce to increase braking efficiency, as described above. It should be appreciated that other pitch attitude control systems can be employed in the aircraft 100 and are also within the scope of the present disclosure.

FIGURE 2A shows the kneeling system 111 in an extended position and FIGURE 2B shows the kneeling system 111 in a retracted position. As used herein, the kneeling system 111 is considered active for maximum braking performance maneuvers (e.g., rejected takeoff, landing on a shortened runway, etc.), when the kneeling system 111 retracts from the position shown in FIGURE 2A toward the position shown in FIGURE 2B, with a maximum retraction corresponding to the maximum kneeling position having the maximum negative wing angle of attack. In other embodiments, the kneeling system 111 can be positioned at any position between the extended and retracted positions based on the required negative wing angle of attack required by the aircraft 100. For example, in maneuvers where the maximum negative wing angle of attack is not required, the kneeling system may only partially retract. The nose landing gear 110 can include an upper mounting point 130 and a tire 140 configured to contact a ground surface G1. In the illustrated embodiments, the kneeling system 111 functions in conjunction with the shock absorbing system of the nose landing gear 110. Although one example embodiment of the kneeling system 111 is shown, any type of system to retract the nose landing gear 110 and cause a negative angle of attack of the wing 102 can be used with the technologies described herein and these systems are also within the scope of the present disclosure. For example, the kneeling system can be separated from the shock absorbing system; can be mechanically, electronically, magnetically, and/or hydraulically actuated; can be integrated into the landing gear deployment/retraction system; etc.

Embodiments of the kneeling system 111 can include a cylinder 132 slidingly associated with a shock absorbing housing 134 that is configured to receive a sliding rod 136 of the nose landing gear 110 therein. The sliding rod 136 can operably couple the tire 140 to the aircraft through the shock absorbing housing 134, the cylinder 132, and the upper mounting point 130, among other components of the nose landing gear. During movement of the aircraft 100 along the ground surface G1, movement of the tire 140 causes the sliding rod 136 to move relative to the shock absorbing housing 134 to absorb shocks and create a smoother ride for the body of the aircraft 100. Various additional components of the shock absorbing system are not shown for the sake of clarity in the FIGURES. In the extended position of the kneeling system 111 shown in FIGURE 2A, the cylinder 132 is pressurized positively, as represented by an arrow 142a, to apply a force urging the shock absorbing housing 134 away from the upper mounting point 130 to the extended position. The extended position of FIGURE 2A may be used during taxiing, takeoff, storage, and other normal operation of the aircraft 100.

When the kneeling system 111 is activated, the nose landing gear 110 transitions toward the retracted position shown in FIGURE 2B. Activation of the kneeling system 111 causes a reduction in the pressure in a pressure chamber 133 of the cylinder 132 is removed, as represented by an arrow 142b, to either apply a force retracting the shock absorbing housing 134 toward the upper mounting point 130, or permitting the weight of the aircraft 100 to move the shock absorbing housing 134 toward the upper mounting point 130, or a combination thereof. In the retracted position of FIGURE 2B, the ground surface G2 is shown at a distance D away from the ground surface G1 shown in FIGURE 2A. The distance D is intended as the retraction range of travel of the kneeling system 111 between the extended and retracted positions. In other embodiments, the shock absorbing housing 134 and the cylinder 132 can be a single component (e.g., a continuous cylinder) with a movable internal component, such as a piston (not shown), allowing the transition between the extended and retracted positions based on pressure differential across the piston.

FIGURE 3 is a functional block diagram of a braking and pitch attitude control system 301 of the aircraft 100 in accordance with aspects of the present disclosure, showing a kneeling system in the nose landing gear 110 and friction braking in the main landing gear assembly 112. As described above, in other embodiments the main landing gear assembly 112 can include systems of the pitch attitude control in addition to or instead of the nose landing gear 110, e.g., an extension system for raising the main landing gear assembly 112, thereby affecting the pitch attitude of the aircraft 100. In the illustrated embodiments, only the nose landing gear 110 includes the pitch attitude control.

The system 301 includes a master brake and kneeling system controller 320 that is configured to manage braking actuation timing and force and the kneeling function based on various input device signals from the aircraft 100. Examples of input device signals sent to and received by the master brake and kneeling system controller 320 are a mechanical brake input device 310 (e.g., hydraulic, pneumatic, mechanical, etc.—from a pilot, personnel manipulating an emergency brake lever, or other manually actuated system), a manual kneeling input device 312 (e.g., a switch, lever, etc.—from a pilot, personnel manipulating the kneeling switch, or other manually actuated system), an automatic brake and kneeling input device 314 (e.g., a signal from an aircraft control system, a potentiometer, a position sensor, an autopilot system, autobraking system, or the like), and other input signals sent to the master brake and kneeling system controller 320. Each of these signals can be interpreted by the master brake and kneeling system controller 320 to actuate the brakes (e.g., a friction brake 332) and change the pitch attitude of the aircraft 100 with a kneeling system (e.g., the kneeling system 111 of FIGURES 2A and 2B) in accordance with a control scheme of the aircraft 100. The master brake and kneeling system controller 320 can additionally be coupled to various other systems and sensors to provide feedback based on, e.g., wheel speed, brake force requirements, aircraft pitch attitude, tire grip, and other similar aspects. Although the master brake and kneeling system controller 320 is shown as a single block in the diagram of FIGURE 3, the control system

may include various separate components that are interconnected to send and receive signals.

In the embodiment of FIGURE 3, the master brake and kneeling system controller 320 is coupled to a pitch attitude controller 322 associated with the nose landing gear 110 and configured to control one or more kneeling pressure supplies 324 arranged in the components of the nose landing gear 110. The kneeling pressure supply 324 can send a pressurized fluid or gas (such as in the directions shown by arrows 142a and 142b in FIGURES 2A and 2B), e.g., to the cylinder 132 of the kneeling system 111. In other embodiments, the nose landing gear 110 can additionally include braking components, such as friction or eddy current brakes that are additionally controlled by the master brake and kneeling system controller 320. The master brake and kneeling system controller 320 can further be coupled to a friction brake controller 330 associated with the main landing gear assembly 112 and configured to control one or more friction brakes 332 arranged in the components of the main landing gear assembly 112. The main landing gear assembly 112 can include any number of wheels and tires that can individually include a friction brake 332.

FIGURE 4 shows a flow chart illustrating a process 400 for operation of a braking and pitch attitude control system 301, e.g., for the aircraft 100 having the kneeling system 111, in accordance with one or more aspects of the present disclosure. The order in which some or all of the process blocks appear in process 400 should not be deemed limiting. Rather, one of ordinary skill in the art having the benefit of the present disclosure will understand that some of the process blocks may be executed in a variety of orders not illustrated, or even in parallel.

In a process block 405, the pitch attitude control system is initiated. The pitch attitude control system can be initiated upon system startup of the aircraft, when the process 400 senses that pitch attitude control is required (manual or automatic input), or when the aircraft is in a mode where pitch attitude control is active (e.g., rejected takeoff or landing

maneuvers). At a decision block 410, the process 400 can decide whether the aircraft is in a rejected takeoff maneuver or a landing maneuver. For example, before the aircraft initiates a rejected takeoff maneuver, the kneeling system 111 will be in the extended position for takeoff to impart positive lift on the aircraft by the wing 102. Similarly, before the aircraft is in a landing maneuver, the nose landing gear 110 will be in a stowed position, or a deployed position without the kneeling system 111 retracted.

When the decision at the decision block 410 is "rejected takeoff," the process 400 advances to a process block 415 where the pressure of the kneeling system 111 is reduced to translate the nose landing gear 110 to the retracted position (e.g., as shown in FIGURE 2B). At this process block 415 and in view of FIGURES 2A and 2B, pressure can be removed from the pressure chamber 133 of the cylinder 132 in the direction of the arrow 142b to transition the kneeling system 111 from the extended position (FIGURE 2A) to the retracted position (FIGURE 2B) and cause the wing 102 to have a negative angle of attack, thereby increasing downforce of the aircraft 100 and the normal force of the tires 140 on the runway, maximizing braking efficiency. For example, when the pilot initiates a rejected takeoff maneuver, they may apply the braking system to a maximum level based on current grip of the tires 140 of the runway during translation of the kneeling system 111 of the nose landing gear 110 to the retracted position, at which point the grip of the tires 140 on the runway will increase, thereby allowing an increased maximum application level of the braking system. In some embodiments, the increased application of the braking system upon transition of the nose landing gear 110 to the retracted position can be automated based on the increased grip of the tire 140 based on, e.g., a sensor and tone wheel measuring tire slip, a load sensor measuring the downforce of the wing 102, or the like, or any combination thereof.

In embodiments where the decision at the decision block 410 is "landing," the process 400 advances to a decision block 420 where the kneeling system 111 can be initiated in the air or on the ground during landing. In embodiments where the decision at

the decision block 420 is "in air," the process 400 advances to a process block 425 where the nose landing gear 110 is deployed while the kneeling system 111 transitions the nose landing gear 110 to the retracted position (FIGURE 2B), or the nose landing gear 110 is deployed fully and then the kneeling system 111 transitions the nose landing gear 110 to the retracted position. In either configuration, it is intended that the nose landing gear 110 is in the retracted position of FIGURE 2B prior to the tire 140 of the nose landing gear 110 contacting the runway.

In embodiments where the decision that the decision block 420 is "on ground," the process 400 advances to a process block 430 where the nose landing gear 110 is deployed and the tire 140 contact the runway during the landing maneuver. Upon contact between the tire 140 in the runway, the process 400 advances to a process block 435 where the pressure of the kneeling system 111 is reduced to translate the nose landing gear 110 to the retracted position (FIGURE 2B). At this process block 435 and in view of FIGURES 2A and 2B, pressure can be removed from the cylinder 132 in the direction of the arrow 142b to transition the kneeling system 111 from the extended position (FIGURE 2A) to the retracted position (FIGURE 2B) and cause the wing 102 to have a negative angle of attack, thereby increasing downforce of the aircraft 100 and the normal force of the tires 140 on the runway, maximizing braking efficiency. For example, when the pilot initiates a landing maneuver and contacts the runway, they may apply the braking system to a maximum level based on current grip of the tires 140 of the runway during translation of the kneeling system 111 of the nose landing gear 110 to the retracted position, at which point the grip of the tires 140 on the runway will increase, thereby allowing an increased maximum application level of the braking system. In some embodiments, the increased application of the braking system upon transition of the nose landing gear 110 to the retracted position can be automated based on the increased grip of the tire 140 based on, e.g., a sensor and tone wheel measuring tire slip, a load sensor measuring the downforce of the wing 102, or

the like, or any combination thereof. It will be appreciated that other control schemes are within the scope of the present disclosure.

A collection of exemplary embodiments, including at least some explicitly enumerated as "ECs" (Example Combinations), providing additional description of a variety of embodiment types in accordance with the concepts described herein are provided below. These examples are not meant to be mutually exclusive, exhaustive, or restrictive; and the claimed subject matter is not limited to these example embodiments but rather encompasses all possible modifications and variations within the scope of the issued claims and their equivalents.

EC A. A pitch attitude control system for an aircraft, comprising:

a nose landing gear assembly operably coupled to a body of the aircraft, the nose landing gear assembly having:

a tire rotatable with respect to the nose landing gear assembly; and

a kneeling system in communication with the pitch attitude control system and being positioned between the body and the tire, the kneeling system having a kneeling cylinder enclosing a pressure chamber and configured to selectively change a distance between the body and the tire such that a pitch attitude of the aircraft changes based on change in pressure within the pressure chamber; and

a pitch attitude controller configured to change the pressure in the pressure chamber of the kneeling cylinder in response to receiving a kneeling signal from an input device of the aircraft, the kneeling signal containing information related to a required attack angle of a wing of the aircraft based on an input amplitude of the kneeling input device, the pitch attitude controller having at least one machine-accessible storage medium that provides instructions that, when executed by the pitch attitude controller, will cause the pitch attitude controller to perform operations, comprising:

when a landing maneuver or a rejected takeoff maneuver is initiated by the aircraft, decrease the pressure in the pressure chamber to retract the kneeling system to a retracted position.

EC B. The pitch attitude control system of EC A, further providing instructions that, when executed by the pitch attitude controller, will cause the pitch attitude controller to perform operations, comprising:

after the landing maneuver or the rejected takeoff maneuver is completed, increase the pressure in the pressure chamber to extend the kneeling system to an extended position.

EC C. The pitch attitude control system of EC A, wherein the nose landing gear assembly further comprises a shock absorber positioned between the body and a tire of the nose landing gear assembly, the shock absorber configured to permit relative movement between the tire and the body.

EC D. The pitch attitude control system of EC C, wherein the pressure chamber of the kneeling cylinder is continuous with a pressure chamber of a shock absorber body.

EC E. The pitch attitude control system of EC C, wherein the pressure chamber of the kneeling cylinder is slidingly associated with a pressure chamber of a shock absorber body.

EC F. The pitch attitude control system of EC A, wherein the attack angle of the wing is negative when the kneeling system is in the retracted position and the tire is in contact with a ground surface, wherein a negative attack angle of the wing imparts a negative lift force on the aircraft during movement of the aircraft along the ground surface.

EC G. The pitch attitude control system of EC A, wherein the aircraft further comprises:

a main landing gear assembly having a friction brake; and

a master brake and kneeling system controller in communication with the pitch attitude controller, the master brake and kneeling system controller configured to apply the friction brake in response to receiving a braking signal from an input device of the aircraft, the braking signal containing information related to a maximum braking force of the aircraft based in part on an amplitude of a negative lift force imparted on the aircraft when the kneeling system is in the retracted position and the attack angle of the wing is negative,

the master brake and kneeling system controller having at least one machine-accessible storage medium that provides instructions that, when executed by the master brake and kneeling system controller, will cause the master brake and kneeling system controller to perform operations, comprising:

applying the friction brake up to the maximum braking force.

EC H. The pitch attitude control system of EC A, wherein the aircraft further comprises a main landing gear assembly having a tire and a main landing gear extension system in communication with the pitch attitude controller and positioned between the body and the tire, the main landing gear extension system configured to extend the distance between the body and the tire to an extended position, wherein the attack angle of the wing is negative when the main landing gear extension system is in the extended position.

EC I. The pitch attitude control system of Claim EC H, wherein the wing has a greater negative angle of attach when the kneeling system in the retracted position and the main landing gear extension system is in extended position.

EC J. A pitch attitude control system for an aircraft, comprising:

a nose landing gear assembly operably coupled to a body of the aircraft, the nose landing gear assembly having:

a tire rotatable with respect to the nose landing gear assembly; and

a deployment system in communication with the pitch attitude control system, the deployment system being positioned between the body and the tire and

configured to transition the nose landing gear assembly between a stowed position and a deployed position; and

a pitch attitude controller configured to move the nose landing gear assembly with the deployment system in response to receiving a kneeling signal from an input device of the aircraft, the kneeling signal containing information related to a required attack angle of a wing of the aircraft based on an input amplitude of the kneeling input device, the pitch attitude controller having at least one machine-accessible storage medium that provides instructions that, when executed by the pitch attitude controller, will cause the pitch attitude controller to perform operations, comprising:

when a landing maneuver or a rejected takeoff maneuver is initiated by the aircraft, transition the deployment system partially toward the stowed position to a retracted position.

EC K. The pitch attitude control system of EC J, further providing instructions that, when executed by the pitch attitude controller, will cause the pitch attitude controller to perform operations, comprising:

after the landing maneuver or the rejected takeoff maneuver is completed, transition the deployment system from the retracted position to the deployed position.

EC L. The pitch attitude control system of EC J, wherein the nose landing gear assembly further comprises a shock absorber positioned between the body and a tire of the nose landing gear assembly, the shock absorber configured to permit relative movement between the tire and the body.

EC M. The pitch attitude control system of EC J, wherein the attack angle of the wing is negative when the deployment system is in the retracted position and the tire is in contact with a ground surface, wherein a negative attack angle of the wing imparts a negative lift force on the aircraft during movement of the aircraft along the ground surface.

EC N. The pitch attitude control system of EC J, wherein the aircraft further comprises:

a main landing gear assembly having a friction brake; and

a master brake and kneeling system controller in communication with the pitch attitude controller, the master brake and kneeling system controller configured to apply the friction brake in response to receiving a braking signal from an input device of the aircraft, the braking signal containing information related to a maximum braking force of the aircraft based in part on an amplitude of a negative lift force imparted on the aircraft when the deployment system is in the retracted position and the attack angle of the wing is negative,

the master brake and kneeling system controller having at least one machine-accessible storage medium that provides instructions that, when executed by the master brake and kneeling system controller, will cause the master brake and kneeling system controller to perform operations, comprising:

applying the friction brake up to the maximum braking force.

EC O. The pitch attitude control system of EC J, wherein the aircraft further comprises a main landing gear assembly having a tire and a main landing gear extension system in communication with the pitch attitude controller and positioned between the body and the tire, the main landing gear extension system configured to extend the distance between the body and the tire to an extended position, wherein the attack angle of the wing is negative when the main landing gear extension system is in the extended position.

EC P. The pitch attitude control system of EC O, wherein the wing has a greater negative angle of attach when the deployment system of the nose landing gear is in the retracted position and the main landing gear extension system is in extended position.

EC Q. A method of changing a pitch attitude of an aircraft during a landing maneuver or a rejected takeoff maneuver, the aircraft having:

a kneeling system operably coupled to a nose landing gear assembly, the kneeling system including a kneeling cylinder enclosing a pressure chamber and configured to selectively change the distance between a body of the aircraft and a tire such that the pitch attitude of the aircraft changes based on a change in pressure within the pressure chamber; and

a pitch attitude controller in communication with the kneeling system, the method comprising:

determining a required negative angle of attack of a wing of the aircraft during a landing maneuver or a rejected takeoff maneuver based on the required braking force;

receiving, by the pitch attitude controller, a kneeling signal from an input device of the aircraft; and

reducing the pressure in the pressure chamber to retract the kneeling system to a retracted position based on an amplitude of the kneeling signal.

EC R. The method of EC Q, wherein during a landing maneuver, the method further comprises:

determining whether the kneeling signal is initiated when the aircraft is in the air or on the ground;

if the kneeling signal is initiated when the aircraft is in the air, deploying the nose landing gear assembly with the kneeling system in the retracted position; and

if the kneeling signal is initiated when the aircraft is on the ground, reducing the pressure in the pressure chamber to retract the kneeling system to a retracted position based on an amplitude of the kneeling signal.

EC S. The method of EC Q, further comprising increasing the pressure in the pressure chamber to extend the kneeling system to an extended position after the landing maneuver or the rejected takeoff maneuver is completed.

EC T. The method of EC Q, wherein the aircraft further includes a main landing gear assembly having a friction brake, and wherein the method further comprises:

receiving a braking signal from an input device of the aircraft, the braking signal containing information related to a maximum braking force of the aircraft based in part on an amplitude of a negative lift force imparted on the aircraft when the kneeling system is in the retracted position and the attack angle of the wing is negative; and

applying the friction brake up to the maximum braking force in response to the braking signal.

In the foregoing description, specific details are set forth to provide a thorough understanding of exemplary embodiments of the present disclosure. It will be apparent to one skilled in the art, however, that the embodiments disclosed herein may be practiced without embodying all of the specific details. In some instances, well-known process steps have not been described in detail in order not to unnecessarily obscure various aspects of the present disclosure. Further, it will be appreciated that embodiments of the present disclosure may employ any combination of features described herein.

The present application may reference quantities and numbers. Unless specifically stated, such quantities and numbers are not to be considered restrictive, but exemplary of the possible quantities or numbers associated with the present application. Also in this regard, the present application may use the term "plurality" to reference a quantity or number. In this regard, the term "plurality" is meant to be any number that is more than one, for example, two, three, four, five, etc. The terms "about," "approximately," "near," etc., mean plus or minus 10% of the stated value. For the purposes of the present disclosure, the phrase "at least one of A and B" is equivalent to "A and/or B" or vice versa, namely "A" alone, "B" alone or "A and B.". Similarly, the phrase "at least one of A, B, and C," for example, means (A), (B), (C), (A and B), (A and C), (B and C), or (A, B, and C), including all further possible permutations when greater than three elements are listed.

It should be noted that for purposes of this disclosure, terminology such as "upper," "lower," "vertical," "horizontal," "fore," "aft," "inner," "outer," "front," "rear," etc., should be construed as descriptive and not limiting the scope of the claimed subject matter. Further, the use of "including," "comprising," or "having" and variations thereof herein is meant to encompass the items listed thereafter and equivalents thereof as well as additional items. Unless limited otherwise, the terms "connected," "coupled," and "mounted" and variations thereof herein are used broadly and encompass direct and indirect connections, couplings, and mountings.

Throughout this specification, terms of art may be used. These terms are to take on their ordinary meaning in the art from which they come, unless specifically defined herein or the context of their use would clearly suggest otherwise.

The principles, representative embodiments, and modes of operation of the present disclosure have been described in the foregoing description. However, aspects of the present disclosure, which are intended to be protected, are not to be construed as limited to the particular embodiments disclosed. Further, the embodiments described herein are to be regarded as illustrative rather than restrictive. It will be appreciated that variations and changes may be made by others, and equivalents employed, without departing from the spirit of the present disclosure. Accordingly, it is expressly intended that all such variations, changes, and equivalents fall within the spirit and scope of the present disclosure as claimed.

CLAIMS

The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows:

1. A pitch attitude control system for an aircraft, comprising:

a nose landing gear assembly operably coupled to a body of the aircraft, the nose landing gear assembly having:

a tire rotatable with respect to the nose landing gear assembly; and

a kneeling system in communication with the pitch attitude control system and being positioned between the body and the tire, the kneeling system having a kneeling cylinder enclosing a pressure chamber and configured to selectively change a distance between the body and the tire such that a pitch attitude of the aircraft changes based on change in pressure within the pressure chamber; and

a pitch attitude controller configured to change the pressure in the pressure chamber of the kneeling cylinder in response to receiving a kneeling signal from an input device of the aircraft, the kneeling signal containing information related to a required attack angle of a wing of the aircraft based on an input amplitude of the kneeling input device, the pitch attitude controller having at least one machine-accessible storage medium that provides instructions that, when executed by the pitch attitude controller, will cause the pitch attitude controller to perform operations, comprising:

when a landing maneuver or a rejected takeoff maneuver is initiated by the aircraft, decrease the pressure in the pressure chamber to retract the kneeling system to a retracted position.

2. The pitch attitude control system of Claim 1, further providing instructions that, when executed by the pitch attitude controller, will cause the pitch attitude controller to perform operations, comprising:

after the landing maneuver or the rejected takeoff maneuver is completed, increase the pressure in the pressure chamber to extend the kneeling system to an extended position.

3. The pitch attitude control system of Claims 1 or 2, wherein the nose landing gear assembly further comprises a shock absorber positioned between the body and a tire of the nose landing gear assembly, the shock absorber configured to permit relative movement between the tire and the body.

4. The pitch attitude control system of Claim 3, wherein the pressure chamber of the kneeling cylinder is continuous with a pressure chamber of a shock absorber body.

5. The pitch attitude control system of Claim 3, wherein the pressure chamber of the kneeling cylinder is slidingly associated with a pressure chamber of a shock absorber body.

6. The pitch attitude control system of any of Claims 1–5, wherein the attack angle of the wing is negative when the kneeling system is in the retracted position and the tire is in contact with a ground surface, wherein a negative attack angle of the wing imparts a negative lift force on the aircraft during movement of the aircraft along the ground surface.

7. The pitch attitude control system of any of Claims 1–6, wherein the aircraft further comprises:

a main landing gear assembly having a friction brake; and

a master brake and kneeling system controller in communication with the pitch attitude controller, the master brake and kneeling system controller configured to apply the friction brake in response to receiving a braking signal from an input device of the aircraft, the braking signal containing information related to a maximum braking force of the aircraft based in part on an amplitude of a negative lift force imparted on the aircraft when the kneeling system is in the retracted position and the attack angle of the wing is negative,

the master brake and kneeling system controller having at least one machine-accessible storage medium that provides instructions that, when executed by the master

brake and kneeling system controller, will cause the master brake and kneeling system controller to perform operations, comprising:

applying the friction brake up to the maximum braking force.

8. The pitch attitude control system of any of Claims 1–7, wherein the aircraft further comprises a main landing gear assembly having a tire and a main landing gear extension system in communication with the pitch attitude controller and positioned between the body and the tire, the main landing gear extension system configured to extend the distance between the body and the tire to an extended position, wherein the attack angle of the wing is negative when the main landing gear extension system is in the extended position.

9. The pitch attitude control system of Claim 8, wherein the wing has a greater negative angle of attach when the kneeling system in the retracted position and the main landing gear extension system is in extended position.

10. A pitch attitude control system for an aircraft, comprising:

a nose landing gear assembly operably coupled to a body of the aircraft, the nose landing gear assembly having:

a tire rotatable with respect to the nose landing gear assembly; and

a deployment system in communication with the pitch attitude control system, the deployment system being positioned between the body and the tire and configured to transition the nose landing gear assembly between a stowed position and a deployed position; and

a pitch attitude controller configured to move the nose landing gear assembly with the deployment system in response to receiving a kneeling signal from an input device of the aircraft, the kneeling signal containing information related to a required attack angle of a wing of the aircraft based on an input amplitude of the kneeling input device, the pitch attitude controller having at least one machine-accessible storage medium that provides

instructions that, when executed by the pitch attitude controller, will cause the pitch attitude controller to perform operations, comprising:

when a landing maneuver or a rejected takeoff maneuver is initiated by the aircraft, transition the deployment system partially toward the stowed position to a retracted position.

11. The pitch attitude control system of Claim 10, further providing instructions that, when executed by the pitch attitude controller, will cause the pitch attitude controller to perform operations, comprising:

after the landing maneuver or the rejected takeoff maneuver is completed, transition the deployment system from the retracted position to the deployed position.

12. The pitch attitude control system of Claims 10 or 11, wherein the nose landing gear assembly further comprises a shock absorber positioned between the body and a tire of the nose landing gear assembly, the shock absorber configured to permit relative movement between the tire and the body.

13. The pitch attitude control system of any of Claims 10–12, wherein the attack angle of the wing is negative when the deployment system is in the retracted position and the tire is in contact with a ground surface, wherein a negative attack angle of the wing imparts a negative lift force on the aircraft during movement of the aircraft along the ground surface.

14. The pitch attitude control system of any of Claims 10–13, wherein the aircraft further comprises:

a main landing gear assembly having a friction brake; and

a master brake and kneeling system controller in communication with the pitch attitude controller, the master brake and kneeling system controller configured to apply the friction brake in response to receiving a braking signal from an input device of the aircraft,

the braking signal containing information related to a maximum braking force of the aircraft based in part on an amplitude of a negative lift force imparted on the aircraft when the deployment system is in the retracted position and the attack angle of the wing is negative,

the master brake and kneeling system controller having at least one machine-accessible storage medium that provides instructions that, when executed by the master brake and kneeling system controller, will cause the master brake and kneeling system controller to perform operations, comprising:

applying the friction brake up to the maximum braking force.

15. The pitch attitude control system of any of Claims 10–14, wherein the aircraft further comprises a main landing gear assembly having a tire and a main landing gear extension system in communication with the pitch attitude controller and positioned between the body and the tire, the main landing gear extension system configured to extend the distance between the body and the tire to an extended position, wherein the attack angle of the wing is negative when the main landing gear extension system is in the extended position.

16. The pitch attitude control system of Claim 15, wherein the wing has a greater negative angle of attach when the deployment system of the nose landing gear is in the retracted position and the main landing gear extension system is in extended position.

17. A method of changing a pitch attitude of an aircraft during a landing maneuver or a rejected takeoff maneuver, the aircraft having:

a kneeling system operably coupled to a nose landing gear assembly, the kneeling system including a kneeling cylinder enclosing a pressure chamber and configured to selectively change the distance between a body of the aircraft and a tire such that the pitch attitude of the aircraft changes based on a change in pressure within the pressure chamber; and

a pitch attitude controller in communication with the kneeling system, the method comprising:

determining a required negative angle of attack of a wing of the aircraft during a landing maneuver or a rejected takeoff maneuver based on the required braking force;

receiving, by the pitch attitude controller, a kneeling signal from an input device of the aircraft; and

reducing the pressure in the pressure chamber to retract the kneeling system to a retracted position based on an amplitude of the kneeling signal.

18. The method of Claim 17, wherein during a landing maneuver, the method further comprises:

determining whether the kneeling signal is initiated when the aircraft is in the air or on the ground;

if the kneeling signal is initiated when the aircraft is in the air, deploying the nose landing gear assembly with the kneeling system in the retracted position; and

if the kneeling signal is initiated when the aircraft is on the ground, reducing the pressure in the pressure chamber to retract the kneeling system to a retracted position based on an amplitude of the kneeling signal.

19. The method of Claims 17 or 18, further comprising increasing the pressure in the pressure chamber to extend the kneeling system to an extended position after the landing maneuver or the rejected takeoff maneuver is completed.

20. The method of any of Claims 17–19, wherein the aircraft further includes a main landing gear assembly having a friction brake, and wherein the method further comprises:

receiving a braking signal from an input device of the aircraft, the braking signal containing information related to a maximum braking force of the aircraft based in part on

an amplitude of a negative lift force imparted on the aircraft when the kneeling system is in the retracted position and the attack angle of the wing is negative; and

applying the friction brake up to the maximum braking force in response to the braking signal.

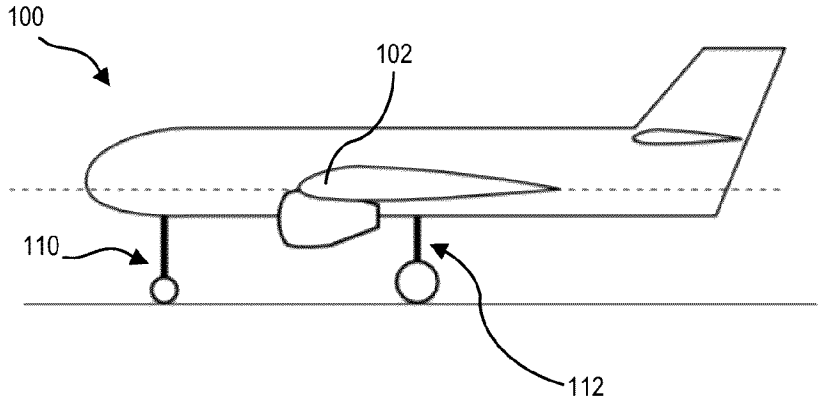


FIG. 1A

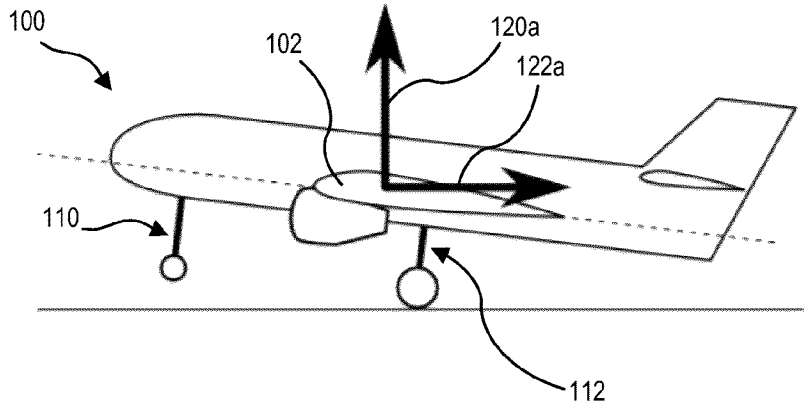


FIG. 1B

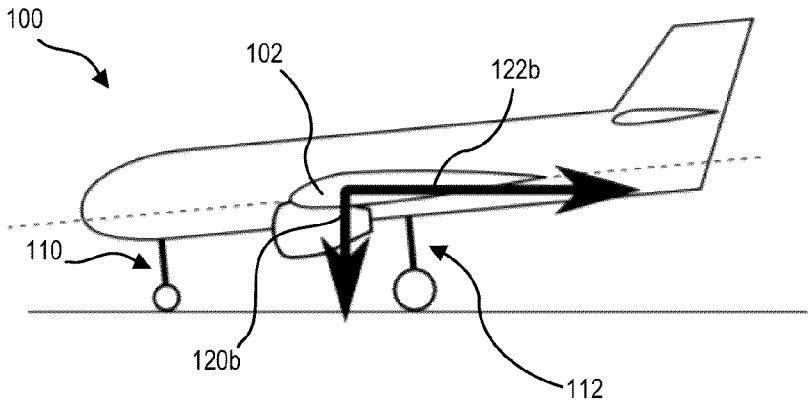


FIG. 1C

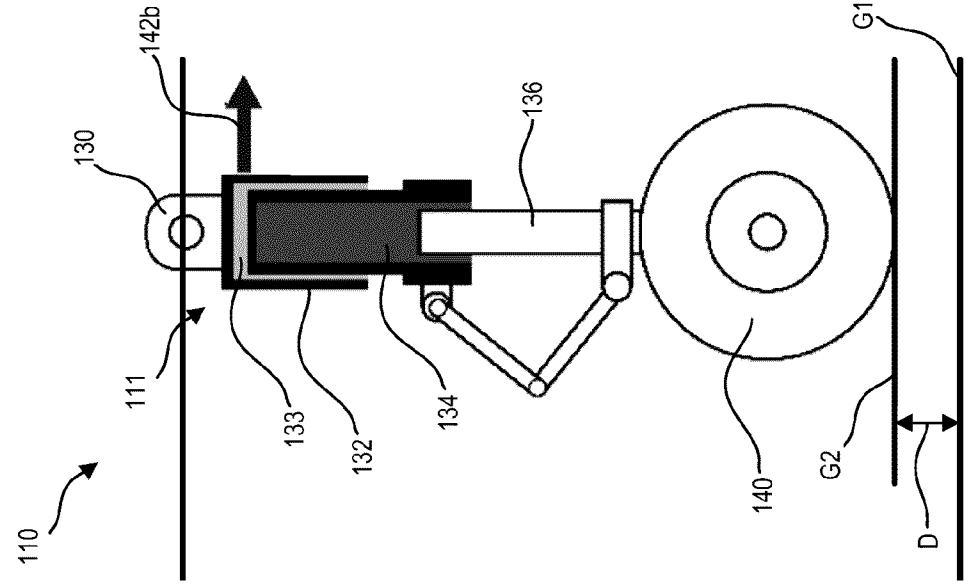

142b
130
136
G1
111
133
132
134
140
G2
D
110

FIG. 2B

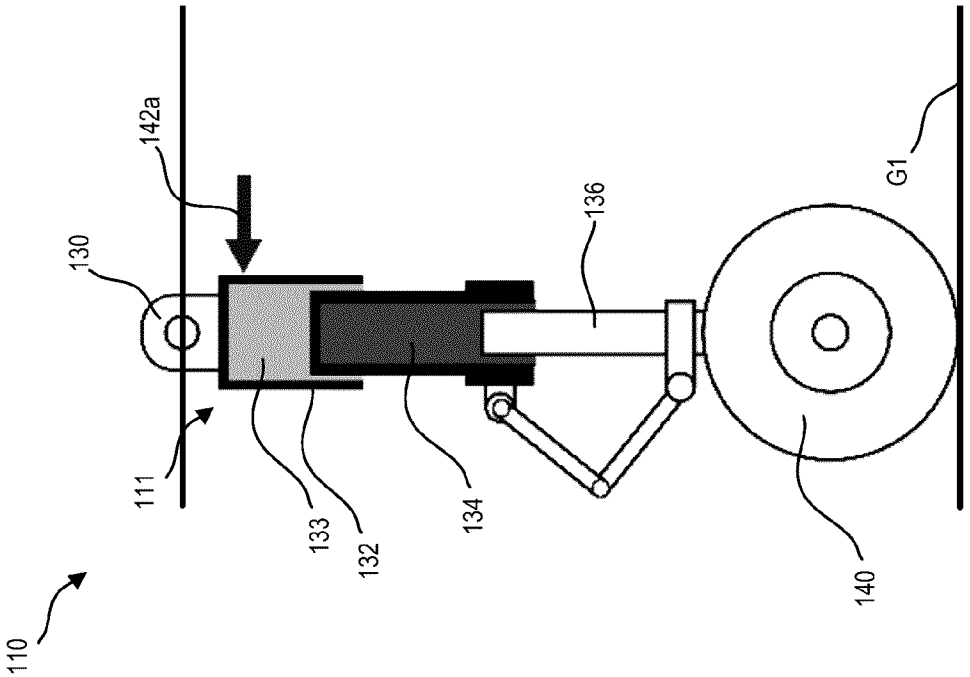

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140
110

FIG. 2A

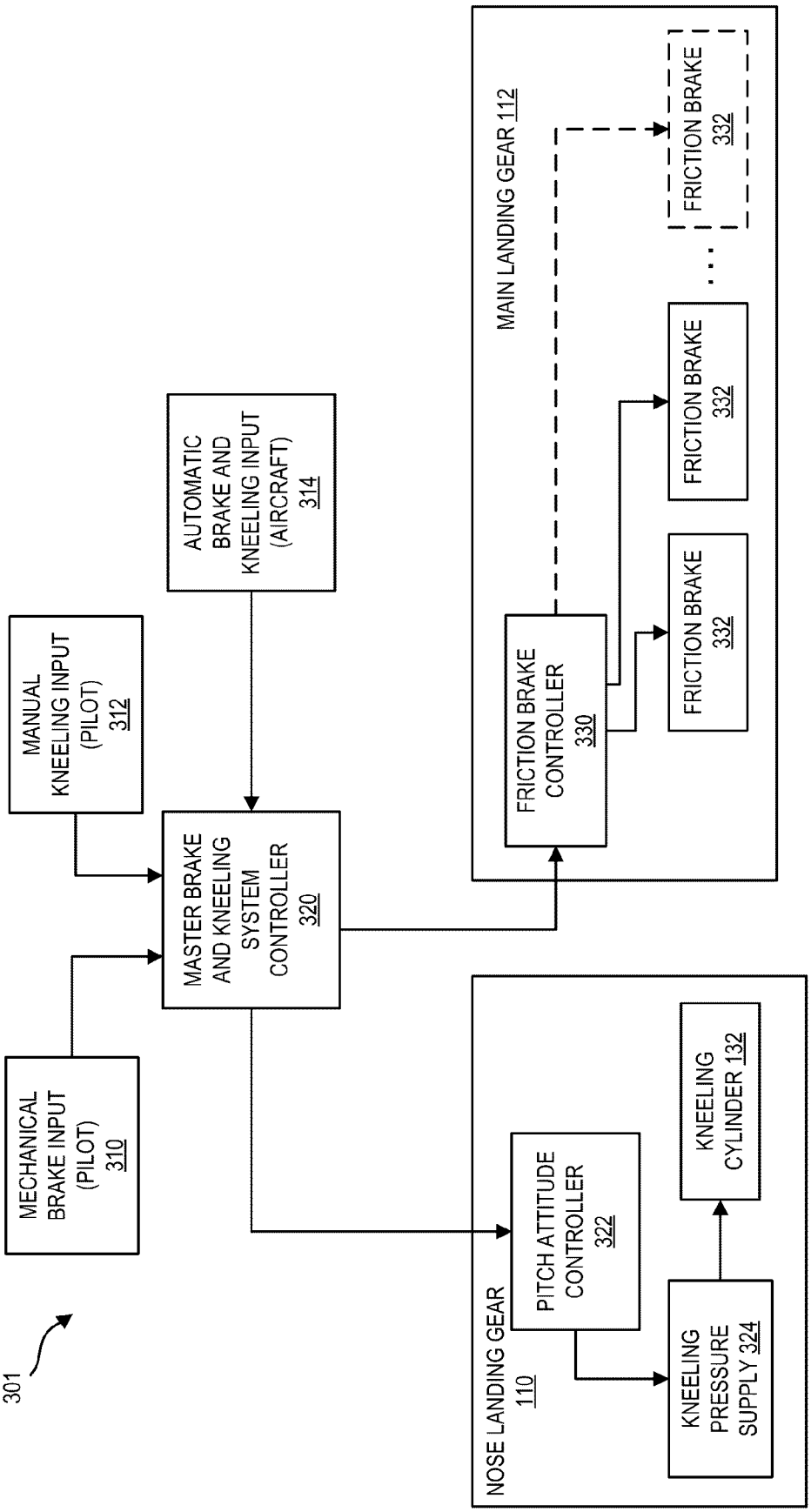

301
MECHANICAL BRAKE INPUT (PILOT) 310
MANUAL KNEELING INPUT (PILOT) 312
AUTOMATIC BRAKE AND KNEELING INPUT (AIRCRAFT) 314
MASTER BRAKE AND KNEELING SYSTEM CONTROLLER 320
NOSE LANDING GEAR 110
PITCH ATTITUDE CONTROLLER 322
KNEELING PRESSURE SUPPLY 324
KNEELING CYLINDER 132
MAIN LANDING GEAR 112
FRICTION BRAKE CONTROLLER 330
FRICTION BRAKE 332
FRICTION BRAKE 332
FRICTION BRAKE 332

FIG. 3

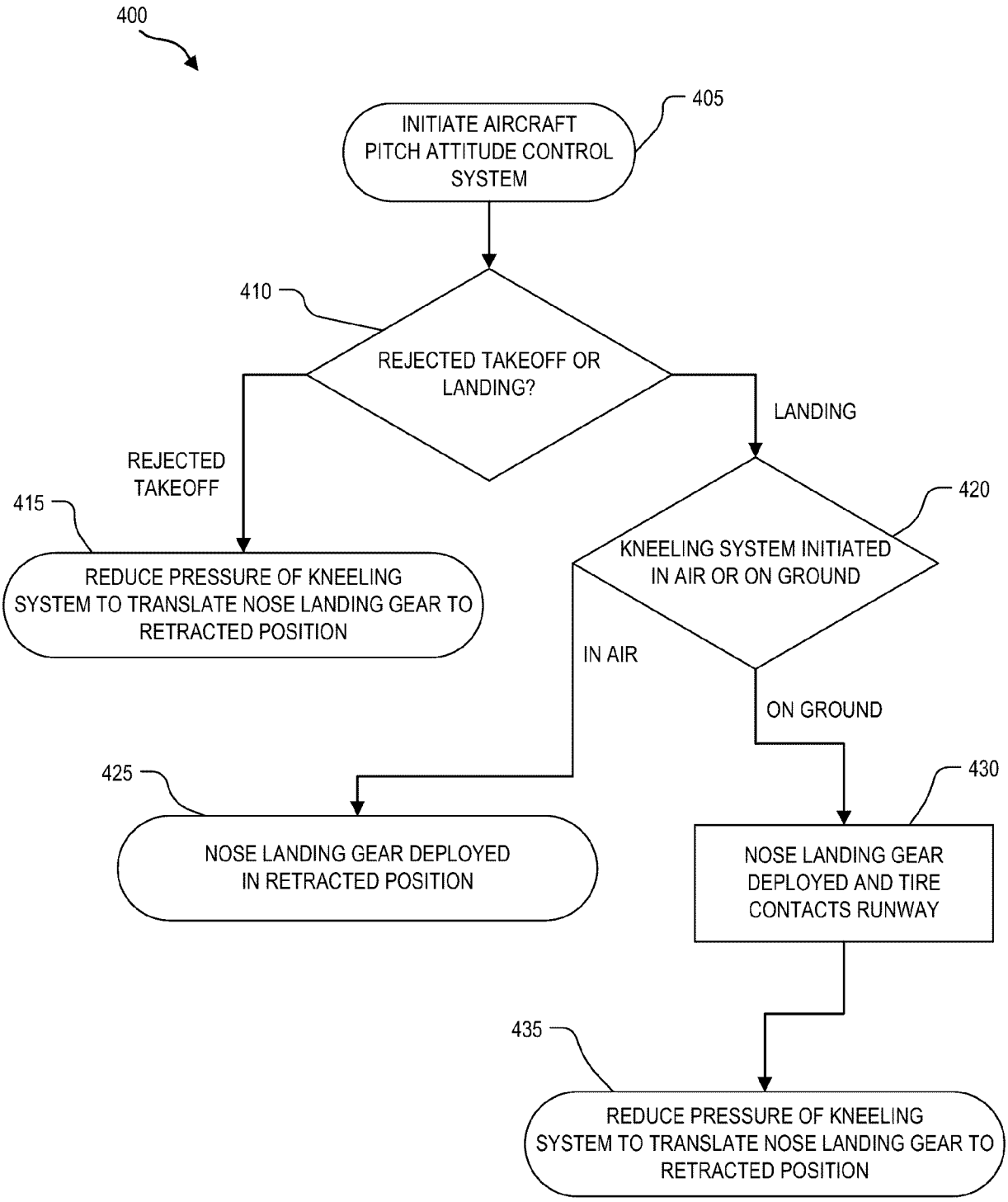

400
INITIATE AIRCRAFT PITCH ATTITUDE CONTROL SYSTEM
405
410
REJECTED TAKEOFF OR LANDING?
REJECTED TAKEOFF
LANDING
415
REDUCE PRESSURE OF KNEELING SYSTEM TO TRANSLATE NOSE LANDING GEAR TO RETRACTED POSITION
420
KNEELING SYSTEM INITIATED IN AIR OR ON GROUND
IN AIR
ON GROUND
425
NOSE LANDING GEAR DEPLOYED IN RETRACTED POSITION
430
NOSE LANDING GEAR DEPLOYED AND TIRE CONTACTS RUNWAY
435
REDUCE PRESSURE OF KNEELING SYSTEM TO TRANSLATE NOSE LANDING GEAR TO RETRACTED POSITION

FIG. 4

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CA2024/051021

A. CLASSIFICATION OF SUBJECT MATTER

IPC: ***B64C 19/00*** (2006.01), ***B64C 25/00*** (2006.01)

CPC: B64C 19/00 (2013.01), B64C 2025/008 (2013.01)

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC: *B64C 19/00* (2006.01), *B64C 25/00* (2006.01)
CPC: B64C 19/00 (2013.01), B64C 2025/008 (2013.01)

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic database(s) consulted during the international search (name of database(s) and, where practicable, search terms used)

FAMPAT (ORBIT)
LAND+, BRAK+, KNEEL, PITCH, DE?ROTATION, INCIDENCE, ATTACK, LIFT, FORCE, DOWN?FORCE, MOMENT

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	FR3018501A1 (CHEVROLLIER, S et al) 18 September 2015 (18-09-2015) ***description, figures 4, 6***	1-20
A	US2764371A (ARMSTRONG, E et al) 25 September 1956 (25-09-1956) ***column 4, line 68- column 5, line 13***	1-20
A	US1716439A (GREY, W. E) 11 June 1929 (11-06-1929) ***description, figures***	1-20
A	US5509623A (SCHMITTLE H) 23 April 1996 (23-04-1996) *** abstract, figures ***	1-20
A	US2009065636A1 (MATHIIEU, G) 12 March 2009 (12-03-2009) *** abstract, figures ***	1-20

☒ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

*	Special categories of cited documents:	"T"	later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"A"	document defining the general state of the art which is not considered to be of particular relevance	"X"	document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"D"	document cited by the applicant in the international application	"Y"	document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"E"	earlier application or patent but published on or after the international filing date	"&"	document member of the same patent family
"L"	document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)		
"O"	document referring to an oral disclosure, use, exhibition or other means		
"P"	document published prior to the international filing date but later than the priority date claimed		

Date of the actual completion of the international search
1 November 2024(1-11-2024)

Date of mailing of the international search report
13 November 2024 (13-11-2024)

Name and mailing address of the ISA/CA
Canadian Intellectual Property Office
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50 Victoria Street
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Facsimile No.: 819-953-2476

Authorized officer

Darren Hubley (819) 639-7856

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US2018015997A1 (ZAMBRANO, G et al) 18 January 2018 (18-01-2018) *** abstract, figures ***	1-20
A	US2021206475A1 ((BUETHE, S et al) 08 July 2021 (08-07-2021) *** abstract, figures ***	1-20

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/CA2024/051021

Patent Document Cited in Search Report	Publication Date	Patent Family Member(s)	Publication Date
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		FR3018500A1	18 September 2015 (18-09-2015)
US2764371A	25 September 1956 (25-09-1956)	ES217833A1	01 December 1955 (01-12-1955)
US1716439A	11 June 1929 (11-06-1929)	None	
US5509623A	23 April 1996 (23-04-1996)	None	
US2009065636A1	12 March 2009 (12-03-2009)	US7708223B2	04 May 2010 (04-05-2010)
		ATE389582T1	15 April 2008 (15-04-2008)
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		BRPI0516920B1	16 January 2018 (16-01-2018)
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		CA2581436C	29 May 2012 (29-05-2012)
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		DE602005005513T2	23 April 2009 (23-04-2009)
		EP1807304A1	18 July 2007 (18-07-2007)
		EP1807304B1	19 March 2008 (19-03-2008)
		FR2877312A1	05 May 2006 (05-05-2006)
		FR2877312B1	12 January 2007 (12-01-2007)
		JP2008518821A	05 June 2008 (05-06-2008)
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		WO2006048519A1	11 May 2006 (11-05-2006)
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		BR102017014950A2	14 February 2018 (14-02-2018)
		CN107618655A	23 January 2018 (23-01-2018)
		CN107618655B	19 August 2022 (19-08-2022)
		EP3269638A1	17 January 2018 (17-01-2018)
		EP3269638B1	01 January 2020 (01-01-2020)
US2021206475A1	08 July 2021 (08-07-2021)	US11535365B2	27 December 2022 (27-12-2022)