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(54) Title: MAGNETIC POSITIVE DETENT FOR HELICOPTER PILOT INPUT

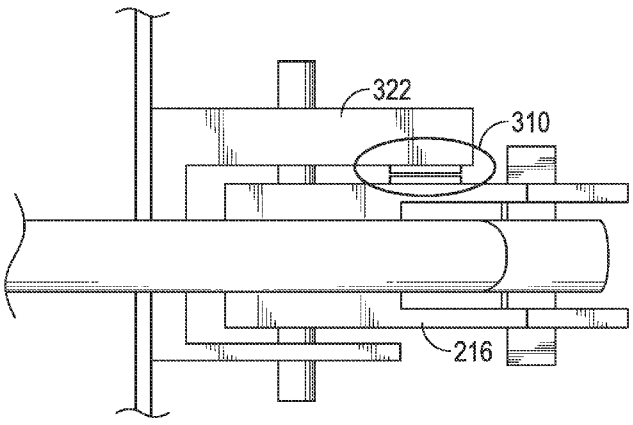

FIG. 3

(57) Abstract: A control system includes at least one lever configured to receive an operator input, a bellcrank coupled to the at least one lever and configured to rotate when the operator input exceeds a threshold, a support structure of the bellcrank which movably holds the bellcrank, and at least one magnet which forms a magnetic field which forms a positive detent between the bellcrank and the support structure of the bellcrank.

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MAGNETIC POSITIVE DETENT FOR HELICOPTER PILOT INPUT

BACKGROUND

[0001] Detents are present on aircraft for pilot assistance. For ease of use, most aircraft controls have detents about a neutral position. So-called return features are typically provided such that, in the absence of input, the control is restored or returned to the neutral position.

[0002] Conventional detents include spring capsules with an adjustable preloaded spring that provides resistance to movement from the neutral position. Another conventional detent includes a cam and follower system, which is also usually adjustable with a spring having a known force or spring constant that must be overcome to displace the control from the neutral position. Both of these detents are costly and time consuming to design and manufacture. Moreover, given the presence of the controls on an aircraft, additional features must be included in case of jamming.

BRIEF SUMMARY

[0003] An embodiment is directed to a method of installing a detent comprising: deploying a pair of magnets in a control system of an aircraft, wherein the magnets are configured based on a breakout force needed to overcome a magnetic detent of the control system.

[0004] In some embodiments, deploying the magnets comprises mounting the magnets at a specified location of the control system.

[0005] In some embodiments, deploying the magnets comprises installing the magnets internal to a pedal or stick control module.

[0006] In some embodiments, the aircraft comprises a helicopter, and wherein the control system is associated with at least one of: collective controls, cyclic controls, and yaw controls.

[0007] In some embodiments, the magnets are permanent magnets.

[0008] In some embodiments, the method further comprises receiving feedback regarding the magnetic detent, and adjusting at least one parameter associated with the magnetic detent based on the feedback.

[0009] In some embodiments, the adjusting of the at least one parameter comprises at least one of selecting a second pair of magnets to replace or supplement the deployed magnets, and modifying a distance between the deployed magnets.

[0010] An embodiment is directed to a control system comprising: at least one lever configured to receive an operator input, a bellcrank coupled to the at least one lever and configured to rotate when the operator input exceeds a threshold, a support structure of the bellcrank which movably holds the bellcrank, and at least one magnet which forms a magnetic field which forms a positive detent between the bellcrank and the support structure of the bellcrank.

[0011] In some embodiments, the at least one magnet which forms the magnetic field comprises a first magnet attached in the bellcrank and a second magnet attached to the support structure of the bellcrank.

[0012] In some embodiments, the at least one magnet is selected to require a breakout force to be provided by a pilot of an aircraft via the operator input in an amount that exceeds the threshold for the bellcrank to rotate.

[0013] In some embodiments, the at least one magnet is installed internal to a pedal or stick control module of an aircraft.

[0014] In some embodiments, the control system is associated with at least one of: collective controls, cyclic controls, yaw controls, or combinations thereof.

[0015] In some embodiments, the bellcrank and support structure are designed with non-magnetic aluminum.

[0016] In some embodiments, the control system further comprises a linkage coupled to the at least one lever and to the bellcrank.

[0017] In some embodiments, the at least one magnet comprises a neodynium magnet.

[0018] An embodiment is directed to a helicopter comprising a control system, such as one or more of the control systems described herein.

[0019] An embodiment is directed to a vehicle comprising a control system, such as one or more of the control systems described herein.

[0020] Additional embodiments are described below.

BRIEF DESCRIPTION OF THE DRAWINGS

[0021] The present disclosure is illustrated by way of example and not limited in the accompanying figures in which like reference numerals indicate similar elements.

[0022] FIG. 1 is a general perspective side view of an exemplary aircraft;

[0023] FIG. 2 is a block diagram of an exemplary control system;

[0024] FIG. 3 illustrates an exemplary magnetic detent;

[0025] FIG. 4 illustrates a flow chart of an exemplary method;

[0026] FIGS. 5A-5B illustrate an exemplary design application;

[0027] FIGS. 6A-6B illustrate an exemplary design application; and

[0028] FIGS. 7A-7B illustrate an exemplary installation for a collective channel.

DETAILED DESCRIPTION

[0029] It is noted that various connections are set forth between elements in the following description and in the drawings (the contents of which are included in this disclosure by way of reference). It is noted that these connections in general and, unless specified otherwise, may be direct or indirect and that this specification is not intended to be limiting in this respect. In this respect, a coupling between entities may refer to either a direct or an indirect connection.

[0030] Exemplary embodiments of apparatuses, systems, and methods are described regarding the design and use of a detent, such as a magnetic positive detent. The detent may be used in connection with an aircraft. For example, the detent may be associated with a

rotorcraft (e.g., helicopter) pilot input. The strength of the detent may be based on a strength of a selected magnet and a distance between magnets.

[0031] Referring now to FIG. 1, a general perspective view of a helicopter 10 is shown. The helicopter 10 includes a main rotor assembly 12 and tail rotor assembly 14. Although a particular helicopter configuration is illustrated and described in the disclosed embodiment, other configurations and/or machines (e.g., other aircraft configurations) may be used in connection with this disclosure such as coaxial helicopters, helicopters with pusher propellers, or fixed wing aircraft.

[0032] Turning to FIG. 2, a control system 200 in accordance with one or more embodiments is shown. The system 200 may include levers 208. The levers 208 may be used to enable an operator (e.g., a pilot) to apply an input force. For example, the operator may push down on the levers 208 in the input direction shown in FIG. 2. Of course, one skilled in the art would appreciate that the operator could also pull up on the levers 208, such that the input direction would point upwards in such an instance. While described in the context of a human pilot, it is understood that aspects could be used in automated pilot control systems or optionally piloted control systems. Further, while shown with dual levers 208, it is understood that the control system 200 can have a single lever or more than two levers in other aspects.

[0033] Based on the downward applied input to the levers 208 shown in FIG. 2, a bellcrank 216 may be caused to rotate in an output direction as shown. The bellcrank 216 may rotate based on a linkage 224 between the levers 208 and the bellcrank 216. While shown as having opposite rotational directions, it is understood that the control system 200 could have the output direction be in the same rotational direction as the linkage 224 in other aspects.

[0034] In order to keep the bellcrank 216 from rotating in the absence of an applied input to the levers 208, a detent may be used. An example of such a detent is shown in FIG. 3. The detent may correspond to two magnets 310. A first of the magnets 310 may be staked in, or coupled to, the bellcrank 216. A second of the magnets 310 may be staked in, or coupled to, a support structure 322 for the bellcrank 216. The first and second magnets 310 may be oriented to attract one another, thereby creating a positive detent. In some embodiments, one

or both of the first and second magnets 310 may include a permanent magnet. The magnets 310 may be neodymium magnets.

[0035] While shown with a simplified linkage 224 between the levers 208 and the bellcrank 216, it is understood that additional linkages could be used to transmit force and that the detent could be disposed in these additional linkages in other aspects. While shown with a pair of magnets, in other aspects, only a single magnet 310 in conjunction with a magnetizable material may be used. By way of example, where one of the magnets 310 is attached to the bell crank 216 and the support structure 322 is made of a magnetizable material such as steel, the requisite magnetic force between the bell crank 216 and support structure 322 is created.

[0036] The strength of the magnets 310 and the distance between the magnets 310 may be selected to control the force needed to be applied at the levers 208 to break or overcome the detent. Typically, the mechanical components of the system 200 are held to tight tolerances, such that the distance between the first and second magnets 310 is also well-controlled. As such, the force needed to be applied at the lever 208 to break or overcome the detent would be repeatable.

[0037] Turning now to FIG. 4, a flow chart of an exemplary method 400 is shown. The method 400 may be executed in connection with one or more systems, components, or devices, such as those described herein. The method 400 may be used to provide a magnetic detent for a control system of an aircraft.

[0038] In block 402, a desired breakout force needed to overcome a detent may be selected. The breakout force may be selected based on a specification or requirement associated with a given control system.

[0039] In block 404, magnets may be selected. The selection of the magnets may be based on the breakout force selected in block 402. The selection of the magnets may be based on a mounting location for the magnets, which may be a function of the control system.

[0040] In block 406, the magnets may be deployed. For example, as part of block 406, the magnets may be mounted at a specified location of the control system.

[0041] In block 408, feedback may be obtained from an operator of the control system regarding the magnetic detent. If the feedback indicates a lack of satisfaction with the detent, one or more parameters associated with the detent may be adjusted. For example, different magnets may be selected to replace or supplement the current/existing magnets, or a distance between the magnets may be modified.

[0042] The method 400 is illustrative. In some embodiments, one or more of the blocks or operations (or a portion thereof) may be optional. In some embodiments, one or more additional blocks or operations not shown may be included. In some embodiments, the blocks or operations may execute in an order or sequence that is different from what is shown in FIG. 4.

[0043] In some embodiments, a magnet installed in a bellcrank may be designed to rotate, e.g., +/- 10 degrees. As described above, one or more magnets may be installed as part of the bellcrank and/or as part of a fixed support. In some embodiments, magnets may be initially inline, with a 0.020 inch gap. A detent force of approximately 5 pounds may be provided.

[0044] Referring to FIGS. 5A-5B, an application example in accordance with one or more embodiments is shown. In FIG. 5A, a first magnet 504 coupled to a fixed support and a second magnet 512 coupled to a rotating bellcrank are shown in a first position. The magnets 504 and 512 may each generally reside at a location or distance from a center of the bellcrank corresponding to a radius 'r' of a circle. In some embodiments, the radius 'r' may be equal to 1 inch. The magnets 504 and 512 might not be rotated or displaced relative to one another in FIG. 5A.

[0045] In FIG. 5B, the magnet 512 is shown as having been rotated at an angle 'ϕ' relative to the positioning of the magnet 512 in FIG. 5A. The displacement 'd' of the magnet 512 may be calculated as: $d = 2*r*\sin(\phi/2)$. Thus, if 'ϕ' equals 10 degrees and 'r' equals 1 inch, 'd' may be equal to 0.174 inches. The detent can be set to where the magnetic force maintains the magnets 512, 504 in alignment or returns them to alignment as shown in FIG. 5A when within a given displacement d, but is insufficient to force the magnets 512, 504 back into alignment when outside of the displacement d.

[0046] Referring to FIGS. 6A-6B, an application example in accordance with one or more embodiments is shown. The application of FIGS. 6A-6B may be analogous to the embodiment of FIGS. 5A-5B, but may include a small offset or gap between magnets.

Specifically, in FIG. 6A, a first magnet 604 that may be coupled to a fixed support and a second magnet 612 that may be coupled to a rotating bellcrank are shown in a first position. The magnets 604 and 612 may be offset from one another by a distance 'x'. In some embodiments, 'x' may be equal to 0.020 inches.

[0047] In FIG. 6B, the magnet 612 may have been moved relative to the positioning of the magnet 612 in FIG. 6A. Specifically, the magnet 612 may be moved by a distance 'd' in a direction that is substantially perpendicular to the direction 'x'. Accordingly, a total distance 'z' between the magnets 604 and 612 may be approximated as a hypotenuse of right triangle: z = sqrt(x^2 + d^2). Thus, if 'x' equals 0.020 inches and 'd' equals 0.174 inches, then 'z' may equal 0.175 inches. For a small offset or gap 'x' and small angle of rotation 'ϕ', 'z' may approximately be equal to 'd'.

[0048] In some embodiments, a magnetic force of cylinders may be solved numerically to relate, e.g., magnetic force to distance. Relative to a theoretical calculation, the actual force at a given distance in practice may be less due to an interaction of magnetic field lines away from an axis of action. In some embodiments, an attraction force at full travel may be preferred to aid a return to a center or neutral position.

[0049] Referring to FIGS. 7A-7B, an application example in accordance with one or more embodiments is shown.

[0050] In FIG. 7A, a first magnet 704 that may be coupled to, or staked in, a fixed support or support bracket and a second magnet 712 that may be coupled to, or staked in, a rotating stick assembly 720 are shown. The stick assembly 720 may correspond to a pilot collective stick assembly. The portion of FIG. 7A denoted by dashed circle 728 is shown in greater detail in FIG. 7B.

[0051] In FIG. 7B, the magnets 704 and 712 are shown as having an offset or gap of 'x', which may be equal to 0.020 inches.

[0052] In some embodiments, magnets may be used to provide a detent with no moving parts. Therefore, such a detent is not susceptible to jamming. The use of the magnets as a detent provides for a simplistic design and dramatically reduces engineering and maintenance costs. The magnets may allow the detent to function in a number of directions (e.g., rotational directions). Machined bellcranks and supports are typically designed with non-

magnetic materials (e.g., non-magnetic aluminum). As such, the bellcranks and supports will not impact the performance of the magnetic detent.

[0053] Use of magnets as part of a detent reduces costs associated with design, fabrication, deployment and maintenance relative to conventional detents. One merely has to specify a pair of magnets and a mounting location as part of the design process. Since the magnets may be staked into existing components, the magnets add very little weight and little to no volume to an existing system. If during operator evaluation the detent is deemed inadequate, it would be possible to specify two new magnets and replace them without having to undergo a major redesign process.

[0054] In some embodiments, such as in connection with legacy mechanical systems, a magnetic detent may be used to provide a cheap alternative to match more expensive aircraft solutions. On more current fly-by-wire aircraft, the magnetic detent would further eliminate lower reliability mechanical parts from a control system. The magnetic detents may be installed internally to a pedal or stick control modules.

[0055] Aspects of the disclosure may be used in connection with one or more control systems, such as one or more control systems associated with an aircraft. For example, in the context of a helicopter, a detent may be used in connection with collective controls, cyclic controls, or yaw controls. Additionally, while described in the context of aircraft, it is understood that aspects could be used in other forms of control systems, such as those for industrial machinery, or vehicles such as locomotives, cars, trucks, boats, or ships.

[0056] As described herein, in some embodiments various functions or acts may take place at a given location and/or in connection with the operation of one or more apparatuses, systems, or devices. For example, in some embodiments, a portion of a given function or act may be performed at a first device or location, and the remainder of the function or act may be performed at one or more additional devices or locations.

[0057] Aspects of the disclosure have been described in terms of illustrative embodiments thereof. Numerous other embodiments, modifications and variations within the scope and spirit of the appended claims will occur to persons of ordinary skill in the art from a review of this disclosure. For example, one of ordinary skill in the art will appreciate that the steps described in conjunction with the illustrative figures may be performed in other than the recited order, and that one or more steps illustrated may be optional.

CLAIMS

What is claimed is:

1. A method of installing a detent comprising:

deploying a pair of magnets in a control system of an aircraft,

wherein the magnets are configured based on a breakout force needed to overcome a magnetic detent of the control system.

2. The method of claim 1, wherein deploying the magnets comprises mounting the magnets at a specified location of the control system.

3. The method of claim 1, wherein deploying the magnets comprises installing the magnets internal to a pedal or stick control module.

4. The method of claim 1, wherein the aircraft comprises a helicopter, and wherein the control system is associated with at least one of: collective controls, cyclic controls, and yaw controls.

5. The method of claim 1, wherein the magnets are permanent magnets.

6. The method of claim 1, further comprising:

receiving feedback regarding the magnetic detent; and

adjusting at least one parameter associated with the magnetic detent based on the feedback.

7. The method of claim 6, wherein the adjusting of the at least one parameter comprises at least one of:

selecting a second pair of magnets to replace or supplement the deployed magnets, and

modifying a distance between the deployed magnets.

8. A control system comprising:

at least one lever configured to receive an operator input;

a bellcrank coupled to the at least one lever and configured to rotate when the operator input exceeds a threshold;

a support structure of the bellcrank which movably holds the bellcrank; and

at least one magnet which forms a magnetic field which forms a positive detent between the bellcrank and the support structure of the bellcrank.

9. The control system of claim 8, wherein the at least one magnet which forms the magnetic field comprises a first magnet attached in the bellcrank and a second magnet attached to the support structure of the bellcrank.

10. The control system of claim 8, wherein the at least one magnet is selected to require a breakout force to be provided by a pilot of an aircraft via the operator input in an amount that exceeds the threshold for the bellcrank to rotate.

11. The control system of claim 8, wherein the at least one magnet is installed internal to a pedal or stick control module of an aircraft.

12. The control system of claim 8, wherein the control system is associated with at least one of: collective controls, cyclic controls, yaw controls, or combinations thereof.

13. The control system of claim 8, wherein the bellcrank and support structure are designed with non-magnetic aluminum.

14. The control system of claim 8, further comprising:

a linkage coupled to the at least one lever and to the bellcrank.

15. A helicopter comprising the control system of claim 8.

16. The control system of claim 8, wherein the at least one magnet comprises a neodynium magnet.

17. A vehicle comprising the control system of claim 8.

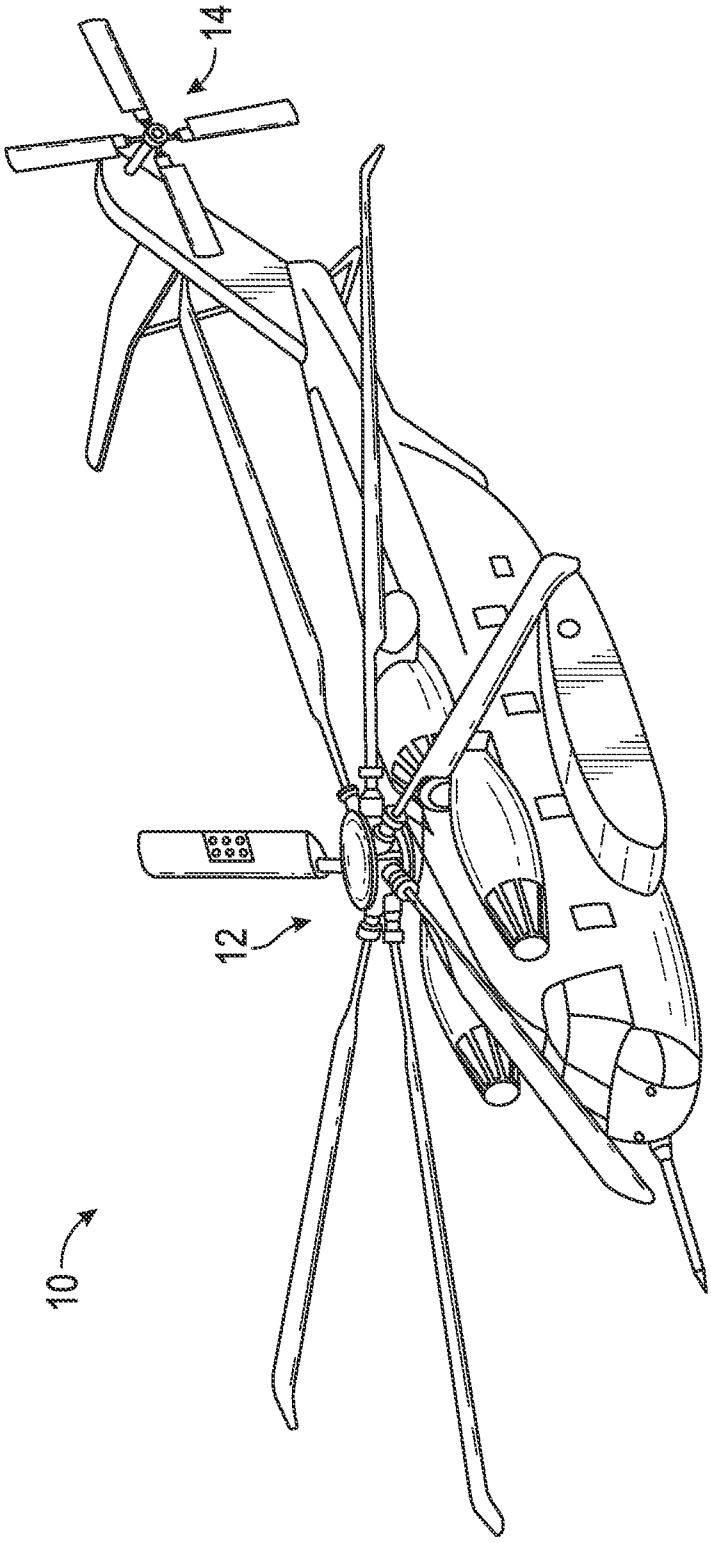

FIG. 1

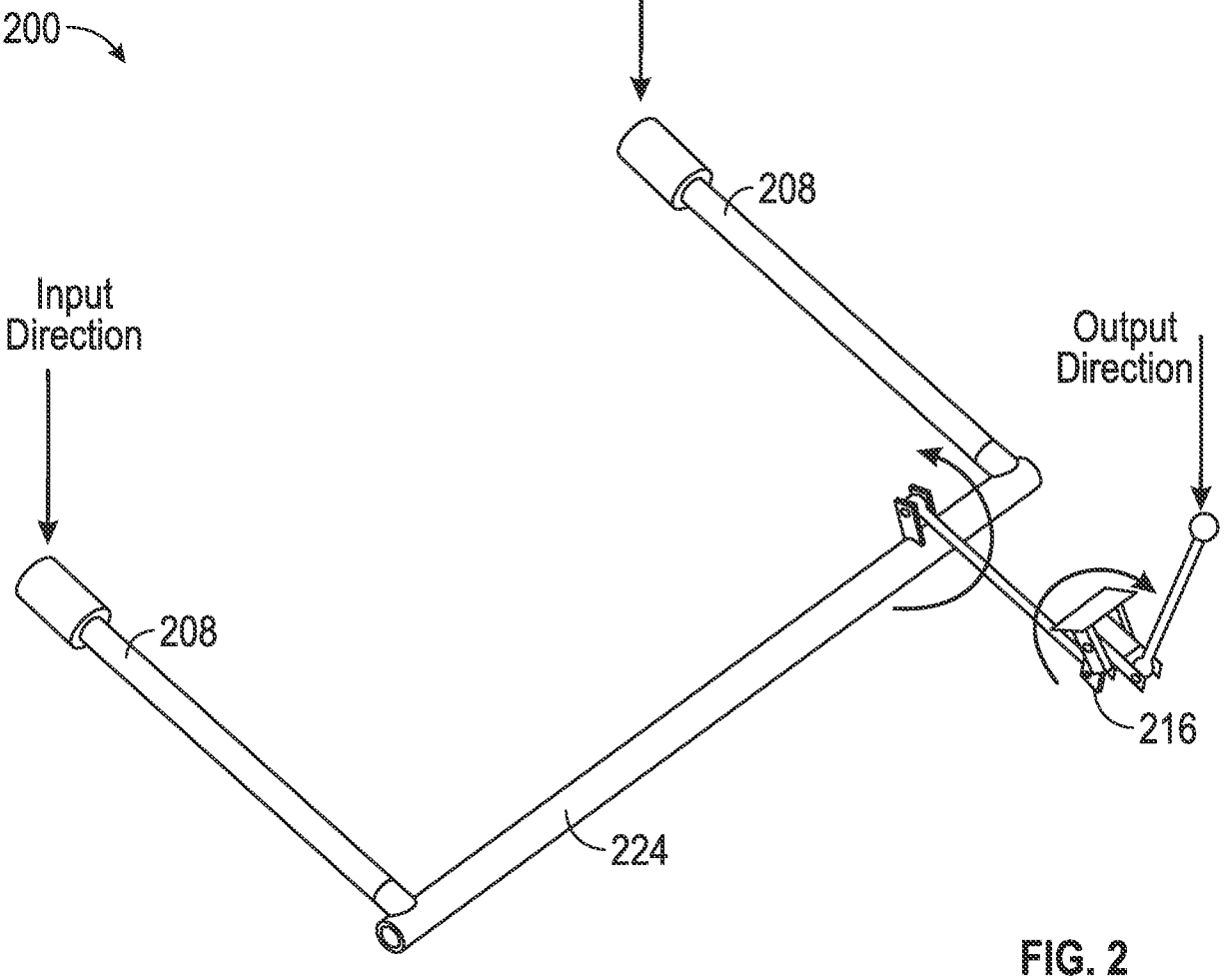
200
208
Input
Direction
Output
Direction
208
216
224

FIG. 2

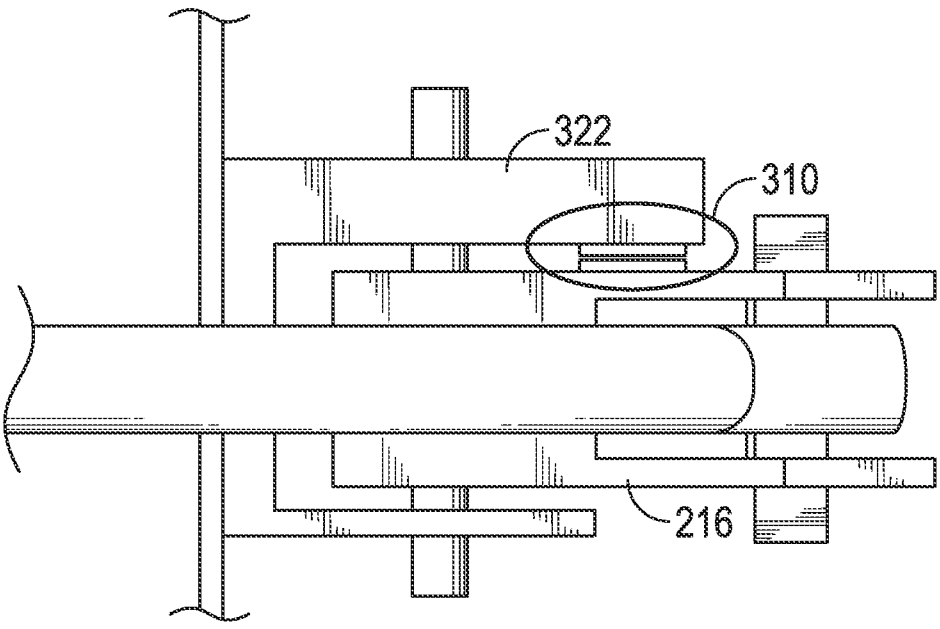
322
310
216

FIG. 3

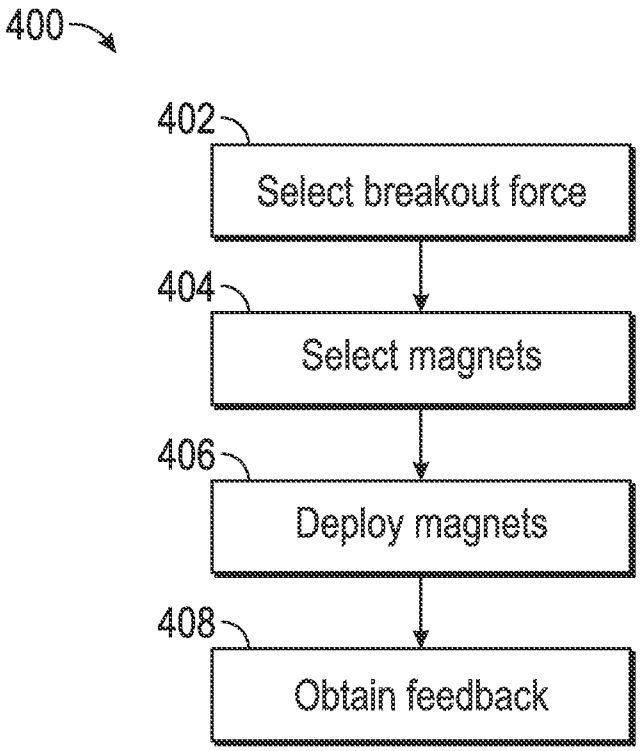

FIG. 4

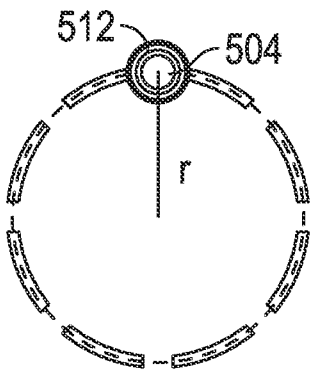

FIG. 5A

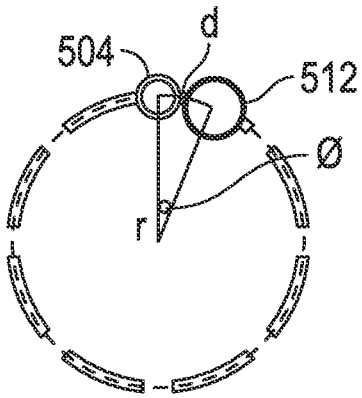

FIG. 5B

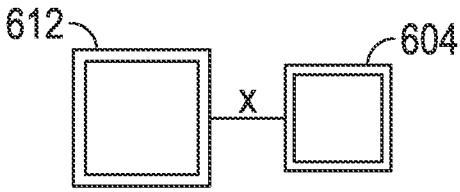

FIG. 6A

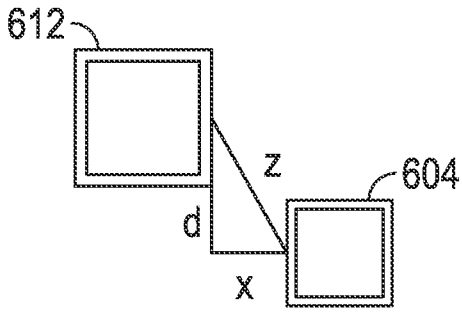

FIG. 6B

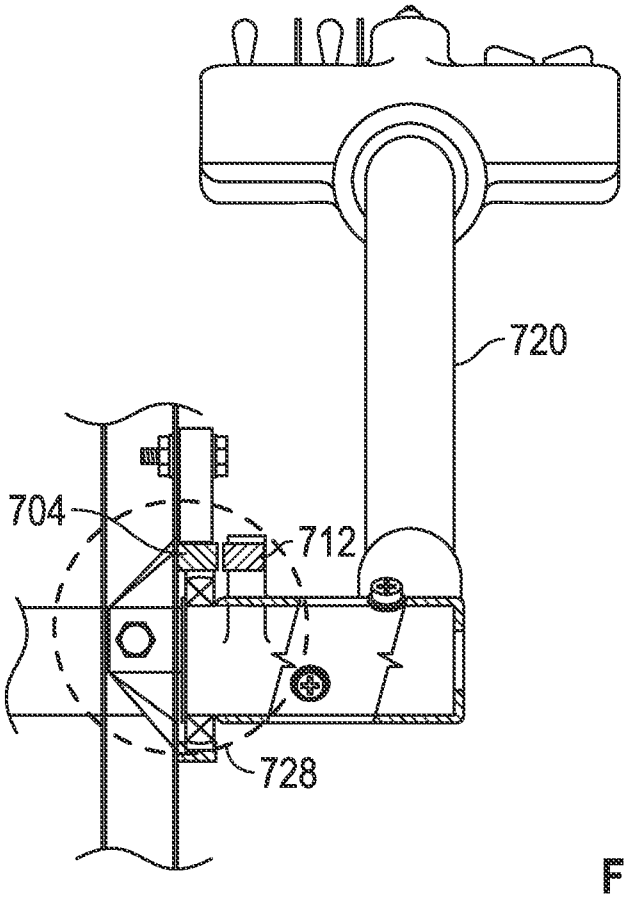

FIG. 7A

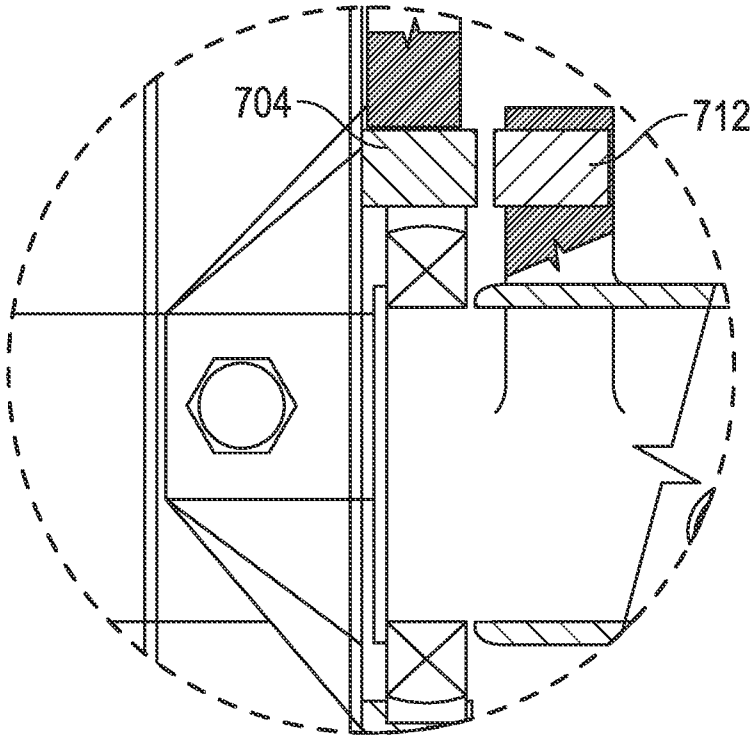

FIG. 7B

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US 14/15764

A. CLASSIFICATION OF SUBJECT MATTER
IPC(8) - H01H 5/02, H01H 3/50 (2014.01)
CPC - H01H 2003/008, H01H 3/50, G05G 5/05
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(8) - H01H 5/02, H01H 3/50 (2014.01)
CPC - H01H 2003/008, H01H 3/50, G05G 5/05

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
IPC(8) - H01H 5/02, H01H 3/50 (2014.01)
CPC - H01H 2003/008, H01H 3/50, G05G 5/05; USPC - 335/220, 74/527 (keyword delimited)

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
Patbase; Google, Freepatentsonline
Search terms used: detent helicopter aircraft airplane pair permanent magnets magnetic yaw cyclic collective opposed adjustable breakout

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 6,424,245 B1 (Rector et al.) 23 July 2002 (23.07.2002), Fig 1a; col 2, ln 9-65; col 4, ln 19-3; col 1, ln 47-57; col 3, ln 56-67; col 6, ln 27-30	1-7
Y	US 2,827,789 A (Oplinger et al.) 25 March 1958 (25.03.1958), col 1, ln 23-30; col 3, ln 43-47; col 12, ln 9-58	1-7
A	US 2008/0303618 A1 (Prest) 11 December 2008 (11.12.2008), entire document	1-7
A	US 3,381,249 A (Younkin) 30 April 1968 (30.04.1968), entire document	1-7
A	US 2012/0144949 A1 (Kim et al.) 14 June 2012 (14.06.2012), entire document	1-7
A	US 2003/0111120 A1 (Aarestad) 19 June 2003 (19.06.2003), entire document	1-7
A	US 2009/0266940 A1 (Miller et al.) 29 October 2009 (29.10.2009), entire document	1-7

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

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"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
"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
"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
"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
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
14 October 2014 (14.10.2014)	07 NOV 2014
Name and mailing address of the ISA/US Mail Stop PCT, Attn: ISA/US, Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-3201	Authorized officer: Lee W. Young PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US 14/15764

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:
This application contains the following inventions or groups of inventions which are not so linked as to form a single general inventive concept under PCT Rule 13.1. In order for all inventions to be examined, the appropriate additional examination fees must be paid.

Group I: Claims 1-7, drawn to a method of installing a detent comprising: deploying a pair of magnets in a control system of an aircraft, wherein the magnets are configured based on a breakout force needed to overcome a magnetic detent of the control system.

Group II: Claims 8-17, drawn to a control system comprising: at least one lever configured to receive an operator input; a bellcrank coupled to the at least one lever and configured to rotate when the operator input exceeds a threshold; a support structure of the bellcrank which movably holds the bellcrank; and at least one magnet which forms a magnetic field which forms a positive detent between the bellcrank and the support structure of the bellcrank.

-- see extra sheet

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☒ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:
1-7

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

☐ No protest accompanied the payment of additional search fees.

International application No.
PCT/US 14/15764

Continuation of Box No. III -- Observations where unity of invention is lacking

The inventions listed as Groups I through II do not relate to a single general inventive concept under PCT Rule 13.1 because, under PCT Rule 13.2, they lack the same or corresponding special technical features for the following reasons:

Special Technical Features
Group I includes the special technical feature of a pair of magnets, the magnets are configured based on a breakout force needed to overcome a magnetic detent of the control system, not included in the other groups.

Group II includes the special technical feature of a bellcrank coupled to the at least one lever and configured to rotate when the operator input exceeds a threshold, not included in the other groups.

Common Technical Features:
The only technical feature shared by Groups I and II that would otherwise unify the groups is a magnetic detent. However, this shared technical feature does not represent a contribution over prior art, because the shared technical feature is disclosed by US 3,381,249 A (Younkin).

Younkin disclose a magnetic detent (col 1, ln 25-28).

As the technical feature was known in the art at the time of the invention, this cannot be considered a special technical feature that would otherwise unify the groups.

Therefore, Groups I-II lack unity under PCT Rule 13.