

(54) **AN ELECTROMECHANICAL HOIST FOR ELIMINATING THE POSSIBILITY OF LOSS OF CONTROL OF A LOAD FOLLOWING A SINGLE POINT FAILURE IN A DRIVE TRAIN AND A METHOD OF OPERATION THEREOF**

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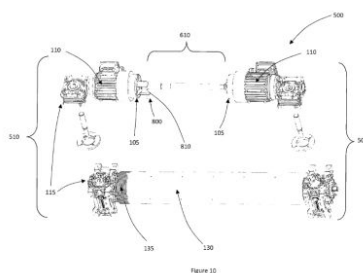
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(57) Abstract:



The present invention relates to a hoist comprising a pair of drive trains connected to a lifting mechanism. The drive trains are both connected to a detection arrangement configured to detect asynchronous movement between the drive trains, and to operate a failsafe brake in the event of detection of asynchronous movement. Invention further comprises a detection arrangement for use in such a hoist.

AN ELECTROMECHANICAL HOIST FOR ELIMINATING THE POSSIBILITY OF LOSS OF CONTROL OF A LOAD FOLLOWING A SINGLE POINT FAILURE IN A DRIVE TRAIN AND A METHOD OF OPERATION THEREOF

5 **Field of the Invention**

[0001] The present invention relates to overcoming problems of hoists being prone to single point failure and the consequences thereof.

Background of the Invention

10 **[0002]** Hoists, such as electromechanical hoists, including those used in stage productions and the like are prone to single point failure in a drive train resulting in the loss of control of the load which may cause damage to the environment, property or personnel.

15 **[0003]** Referring to figure 1, there is shown a prior art electromechanical hoist 100 . The hoist 100 comprises an electric motor 110, such as an AC, DC, induction, universal or the like electric motor 110 mechanically coupled to a load shaft 120, turning a lifting means 130 to raise and lower a load 125 via a lifting medium 135.

20 **[0004]** Sometimes, between the load shaft 120 and the motor 110 is a gear reducer 115. The reducer 115 typically takes the form of a gearbox but may also provide reduction by means of chains and sprockets, belt arrangements and the like. A gear reducer 115 is not always required, and in some embodiments, the motor 110 may act on the load shaft 120 directly.

25 **[0005]** A failsafe brake 105 is fitted to the motor 110 in such a manner as the motor 110 is usually between the failsafe brake 105 and the load shaft 120, although other arrangements are possible. In all embodiments of the hoist 100, the failsafe brake 105 acts to hold the load shaft 120 in place when stationary and also to dynamically arrest the load shaft 120 in an emergency. In other embodiments where the load shaft 120 is not arrested by means of the motor control system, the failsafe brake 105 is used to arrest the load shaft 120 in normal operation as well as in an emergency.

30 **[0006]** In other designs, such as the electromechanical hoist 200 shown in Figure 2, a statically and dynamically irreversible gear reducer 205 (such as a worm drive) is employed instead of a reversible gear reducer 115 and a failsafe brake 105.

[0007] Attaching the load 125 to the lifting means 130 is a lifting medium 135 which may take the form of (including but not limited to) metallic wire ropes (such as steel, stainless steel, aluminium or the like), non-metallic ropes (such as ropes comprising organic or synthetic fibres), lifting link chains, roller chains, flat steel bands and flat fabric tapes.

[0008] A lifting means 130 interfaces between the lifting medium 135 and the load shaft 120. The lifting means may comprise a rotating grooved or un-grooved metallic or non-metallic drum, a spool or "pile winding" drum, a capstan drive, chain drive sprocket and the like.

[0009] However, these existing arrangements suffer from the disadvantage of being prone to a single point mechanical or structural failure in the drive train leading to a loss of control of the load.

[0010] Specifically, referring to the prior art hoist 100 is shown in figure 1, the hoist 100 will irretrievably lose control (i.e. drop) of the load 125 should there occur a single mechanical or structural failure at any point in the drive train between the failsafe brake 105 and the lifting means 130.

[0011] Furthermore, referring to figure 2, showing the prior art hoist 200 comprising the statically and dynamically irreversible gear reducer 205, the hoist 200 will irretrievably lose control (drop) of the load should there occur a single mechanical or structural failure at any point in the drive train between the motor 110 and the lifting means 130.

[0012] In an attempt to reduce to reasonably acceptable levels of risk the consequences of a single point failure, at least two conventional arrangements exist in current standards and codes of practice.

[0013] The apparatus shown in figure 3 is referenced in Australian standard AS1418.1 and represents the most stringent requirements currently implemented.

[0014] Specifically, the hoist 300 in Figure 3 utilises a full load rated failsafe brake 305 to arrest the load should there be a single point failure in the drive train. Coupled to the failsafe brake 305 rotor shaft is an overspeed detection device or tachometer 315 which monitors the rotational speed of the load shaft 120 and lifting means 130 so as to detect when the rotational speed of the shaft 120 exceeds a predetermined design limitation (e.g. AS1418 mandates this activation must occur at $\leq 150\%$ of the rated maximum speed of the hoist). Once the tachometer 315 detects excessive rotational

speed of the load shaft 120 or lifting means 130, the tachometer 350 causes the failsafe brake 305 to engage. However, problems with the hoist 300 remain. Specifically, the hoist 300 does not prevent loss of control of the load following a single point failure in the drive train, but detects this loss of control of the load and brings the load safely under control via means of the full load second failsafe brake.

[0015] A further disadvantage of the hoist 300 is the requirement for a large and expensive high torque failsafe brake 305 and the additional overspeed detection device to trigger the failsafe brake 305. The failsafe brake 305 is designed to stop the full load on the hoist (i.e. not the full load divided by the gearing of the gear reducer). Since the gear reduction may be in order of 50:1, the cost of the failsafe brakes 305 may be largely increased.

[0016] Yet further, the hoist 300 suffers from disadvantages in applying higher dynamic braking torque to the shaft 120 when applying the failsafe brake 305 from an overspeed condition. Yet further, the hoist 300 has disadvantages in requiring additional reinforcing in the interface to the building structure and the hoist 300 to be capable of withstanding the shock loads applied when the failsafe brake 305 is employed.

[0017] Referring now to the apparatus shown in figure 4, which is used for reducing the levels of risk consequent to a single point failure in a drive train. This design is most commonly employed in Europe and calls for the implementation of two independent failsafe brakes 410 and 420. Each failsafe brake 410, 420 comprises sufficient capacity to meet the braking requirements of the design loads of the hoist 400. This apparatus is useful in that the failsafe brakes need only be designed to hold the load once it is geared downwardly.

[0018] If the failsafe brakes 410, 415 are employed, the hoist 400 must be configured such that it is not possible for their simultaneous application so as to reduce the risk of shock loads from excessive braking torque to the load shaft 120. Furthermore, the design requires very generous safety factors in the gear reducer 420, load shaft 120 and other componentry.

[0019] The apparatus shown in hoist 400 in Figure 4 relies on the over dimensioning of gear and motor components to justify excluding a single point failure in a drive train from hoist design risk assessments.

[0020] Furthermore, the apparatus shown in Figure 3 requires first that the load be “dropped” (i.e. losing control of the load) before being able to detect the overspeed condition of the load so as to engage the failsafe brake 305 to “catch” the load.

[0021] The apparatus shown in Figure 4 requires over engineering, which may include the diligent design and testing of critical load-bearing components of the drive train to greatly reduce the probability of the loss of control of the load following a single point failure of the drive train, however, the apparatus does not completely eliminate the possibility of a single point failure of the drive train.

[0022] While hoist 400 comprises advantages in being lighter, smaller and cheaper to build and requires less shock loading than the hoist 300, the hoist 400 is still prone to loss of control of the load following a single point failure in the drive train, although the probability of such a failure is greatly reduced).

[0023] The present invention seeks to provide an electromechanical hoist that eliminates the possibility of a loss of control of the load following a single point failure in a drive train and a method of operating thereof, which will overcome or substantially ameliorate at least some of the deficiencies of the prior art, or at least provide an alternative.

[0024] It is to be understood that, if any prior art information is referred to herein, such reference does not constitute an admission that the information forms part of the common general knowledge in the art, in Australia or any other country.

Summary

[0025] According to an aspect of the present invention, an electromechanical hoist for eliminating the possibility of loss of control of the load following a single point failure in a drive train is provided, the hoist comprising:

- a. a plurality of redundant drive trains, each drive train comprising a respective motor; and
- b. a drive train characteristic monitor adapted to detect asymmetry between the respective drive trains in use.

[0026] In one embodiment, the drive train characteristic monitor is adapted to monitor rotational speed.

[0027] In one embodiment, each drive train comprises a respective tachometer.

- [0028] In one embodiment, the drive train characteristic monitor is operably coupled to each respective tachometer so as to be adapted for determining the rotational velocity of each respective drive train.
- 5 [0029] In one embodiment, the drive train characteristic monitor is adapted to monitor stator current.
- [0030] In one embodiment, the drive train characteristic monitor is adapted to monitor stator current frequency difference.
- [0031] In one embodiment, the drive train characteristic monitor is adapted to monitor stator current phase difference.
- 10 [0032] In one embodiment, the drive train characteristic monitor is operably coupled to each respective motor so as to be adapted for monitoring the motor stator current.
- [0033] In one embodiment, each drive train comprises one or more gear reducers.
- [0034] In one embodiment, the gear reducer is operably coupled between the respective motor and a lifting means.
- 15 [0035] In one embodiment, each drive train comprises a respective failsafe brake.
- [0036] In one embodiment, the drive train characteristic monitor is operably coupled to each respective failsafe brake.
- [0037] In one embodiment, in use, the drive train characteristic monitor is adapted to actuate both failsafe brakes upon detecting asymmetry between the respective motors.
- 20 [0038] In one embodiment, the drive train characteristic monitor is operably coupled to a rotational control circuit of each of the respective motors.
- [0039] In one embodiment, in use, the drive train characteristic monitor is adapted to stop the rotation of both motors upon detecting asymmetry between the respective motors.
- 25 [0040] **According to another aspect of the present invention, a method of operating an electromechanical hoist for eliminating the possibility of loss of control of the load is provided following a single point failure in a drive train, the method comprising detecting asymmetry between respective motors of redundant drive trains.**

[0041] In one embodiment, detecting asymmetry comprises monitoring a rotational speed difference.

[0042] In one embodiment, detecting asymmetry comprises monitoring a motor stator current characteristic difference.

5 **[0043]** In one embodiment, the motor stator current characteristic is a frequency characteristic.

[0044] In one embodiment, the motor stator current characteristic is a phase characteristic.

10 **[0045]** In one embodiment, the motor stator current characteristic is a magnitude characteristic.

[0046] In one embodiment, the method further comprises actuating a failsafe brake of each drive train of the redundant drive trains upon detecting asymmetry.

[0047] In one embodiment, the method further comprises stopping the rotation of both motors upon detecting asymmetry.

15 **[0048]** In another aspect, the invention may be said to consist in a detection arrangement for detecting asymmetry in a pair of drive trains in a hoist.

[0049] In another aspect, the invention may be said to consist in a detection mechanism for detecting asymmetry in a pair of drive trains in a hoist, the detection arrangement comprising:

- 20
- a. a detection arrangement configured for detecting asymmetry in a pair of drive trains,
 - b. an actuation arrangement configured for actuating a braking mechanism in the event of the detection of asymmetry in said pair of drive trains.

Electronically controlled

25 **[0050]** In one embodiment, the detection arrangement comprises

- a. a controller including
 - i. a receiver for receiving signals from sensors,
 - ii. a processor for processing information according to a set of instructions

- iii. digital storage media configured for storing instructions for:
 - A. receiving a signal from sensors indicative of motion in each of the drive trains; and
 - B. comparing the received signals in real-time.

- 5 **[0051]** In one embodiment, the actuation arrangement comprises
- a. a transmitter for transmitting an actuation signal;
 - b. digital storage media configured for storing instructions for
 - A. generating an actuation signal in response to the comparison of the received signals.
- 10 **[0052]** In one embodiment, the hoist comprises at least one or more braking mechanisms configured for braking each of the drive trains, and the actuation signal is configured to actuate braking by said at least one or more braking mechanisms.
- [0053]** In one embodiment, the detection arrangement comprises at least one or more sensors for sensing motion in each of the drive trains.
- 15 **[0054]** In one embodiment, the sensors are configured for sensing one or more selected from:
- a. rotational velocity of the drive trains,
 - b. motor stator current of a motor in each of the drive trains;
 - c. frequency of the drive trains
- 20 d. frequency of the motor stator current
- e. magnitude of the motor stator current, and
 - f. strain in the drive trains.
- [0055]** In one embodiment, the sensors are configured for sensing a magnitude characteristic in each drive train.
- 25 **[0056]** In one embodiment, the detection arrangement is configured for detecting asymmetry in one or more selected from:
- a. rotational velocity of the drive trains,

- b. motor stator current of a motor in each of the drive trains;
- c. frequency of the drive trains
- d. frequency of the motor stator current
- e. magnitude of the motor stator current, and
- 5 f. strain in the drive trains.

[0057] In one embodiment, the digital media is configured for storing instructions for generating an alert signal to inform an operator of the detected asymmetry.

Mechanically controlled

10 **[0058]** In one embodiment, the detection arrangement is a mechanical detection arrangement.

[0059] In one embodiment, the mechanical detection arrangement comprises

- a. a linkage extending between each drive train;
- b. wherein the linkage is configured to move in the event of asymmetry of rotational movement of each drive train.

15 **[0060]** In one embodiment, the linkage comprises a

- a. fixed member securely connected to a first drive train; and
- b. a moving member configured to move rotationally with the second drive train,
- c. wherein the shaft and the moving member are threadably engaged at a threaded interface.

20 **[0061]** In one embodiment, the the fixed member is a shaft.

[0062] In one embodiment, the moving member is configured to move longitudinally along the second drive train.

[0063] In one embodiment, the moving member is keyed onto the second drive train for longitudinal moment along the second drive train.

25 **[0064]** In one embodiment, the actuation arrangement comprises a sensor configured to detect longitudinal movement of the moving member.

[0065] In one embodiment, the sensor is one or more selected from

- a. a light sensor,
- b. a proximity sensor,
- c. a magnetic induction sensor;
- d. a magnetic sensor;
- 5 e. or any other suitably engineered sensor.

[0066] According to another aspect, the invention may be said to consist in a detection mechanism for detecting asymmetry in a pair of drive trains in a hoist, the detection arrangement comprising:

- a. a controller including
 - 10 i. a receiver for receiving signals from sensors,
 - ii. a transmitter for transmitting an actuation signal;
 - iii. a processor for processing information according to a set of instructions
 - iv. digital storage media configured for storing instructions for:
 - 15 A. receiving a signal from sensors indicative of motion in each of the drive trains;
 - B. comparing the received signals in real-time;
 - C. generating an actuation signal for actuating the restriction of motion of at least one or more drive trains.

20 **[0067] According to another aspect, the invention may be said to consist in a hoist comprising a detection arrangement as described.**

[0068] According to another aspect, the invention may be said to consist in a hoist comprising

- a. a lifting mechanism,
- 25 b. a pair of drive trains, each drive train being independently operatively coupled to the lifting mechanism, wherein each drive train comprises at least a prime mover; and

- c. a detection mechanism comprising
 - i. a detection arrangement configured for detecting asymmetry in a pair of drive trains,
 - ii. an actuation arrangement configured for actuating a braking mechanism in the event of the detection of asymmetry in said pair of drive trains.

[0069] In another aspect, the invention may be said to consist in a method of operating an electromechanical hoist for reducing the possibility of loss of control of a load following a single point failure in a drive train, the method comprising the steps of

- a. providing a hoist comprising a pair of drive trains operatively coupled to a lifting mechanism
- b. detecting asymmetry between respective drive trains.

[0070] In one embodiment, each of the drive trains comprises a braking mechanism, and the method comprises the step of actuating a braking mechanism in each of the drive trains in the event of detecting a threshold level of asymmetry in the respective drive trains.

[0071] In one embodiment, the step of detecting asymmetry comprises the step of monitoring a rotational speed difference in each drive train.

[0072] In one embodiment, each of the drive trains comprises a motor, and the step of detecting asymmetry comprises the step of monitoring the difference between motor stator current in each drive train.

[0073] In one embodiment, the step of detecting asymmetry comprises the step of monitoring the frequency of the motor stator current of a motor in each drive train.

[0074] In one embodiment, the step of detecting asymmetry comprises the step of monitoring the difference between phase characteristics of the motor stator current in each motor.

[0075] In one embodiment, the step of detecting asymmetry comprises the step of monitoring the difference between the magnitude of the motor stator current in each motor.

[0076] In one embodiment, the method further comprises the step of actuating a failsafe brake of each drive train of the redundant drive trains upon detecting asymmetry.

[0077] In one embodiment, the method further comprises the step of stopping the rotation of a motor in each drive train upon detecting asymmetry.

5 **[0078]** Other aspects of the invention are also disclosed.

Brief Description of the Drawings

[0079] Notwithstanding any other forms which may fall within the scope of the present invention, a preferred embodiments of the invention will now be described, by way of example only, with reference to the accompanying drawings in which:

10 **[0080]** **Figure 1** shows a typical hoist in accordance with the prior art, such hoist being prone to loss of control of a load following a single point failure in a drive train;

[0081] **Figure 2** shows an alternative design to Fig 1 where the gear reducer and failsafe brake in Fig 1 are replaced with a statically and dynamically irreversible gear reducer, such a hoist yet being prone to loss of control of the load following a single point failure in a drive train;

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[0082] **Figure 3** shows an attempt of the prior art in dealing with the loss of control of the load following a single point failure in the drive train in employing a redundant failsafe brake proximate to the load and actuated by the detection of the loss of control of the load, by means of detection of an overspeed condition;

20 **[0083]** **Figure 4** shows an attempt of the prior art in reducing the probability of a single point failure in a drive train by employing oversized components within the drive train;

[0084] **Figure 5** shows an electromechanical hoist for eliminating the possibility of loss of control of the load following a single point failure in a drive train, the electromechanical hoist comprising redundant drive trains in accordance with an embodiment of the present invention;

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[0085] **Figure 6** shows the electromechanical hoist of Fig. 5 for eliminating the possibility of loss of control of the load following a single point failure in a drive train, the electromechanical hoist being characteristic in comprising a drive train characteristic monitor adapted to detect asymmetry between the respective motors in use, in accordance with a preferred embodiment of the present invention;

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[0086] **Figure 7** shows a perspective view of a mechanical arrangement of the electromechanical hoist of Fig. 5 in accordance with an embodiment of the present invention;

[0087] **Figure 8** shows a cutaway top view of a detection mechanism mounted to a drive train at each end;

[0088] **Figure 9** shows a close up of the cutaway view of figure 8;

[0089] **Figure 10** shows a top perspective assembly view of a hoist with a mechanically operable detection mechanism; and

[0090] **Figure 11** shows a close up perspective view of the hoist of figure 10, showing the detection mechanism mounted to a drive train at each end.

Description of Embodiments

[0091] It should be noted in the following description that like or the same reference numerals in different embodiments denote the same or similar features.

Apparatus

[0092] Referring to figures 5- 11 there is shown an electromechanical hoist 500 adapted to reduce, and preferably eliminate the possibility of loss of control of the load following a single point failure in a drive train. As will be described in further detail below, the hoist 500 utilises the characteristic features of a redundant drive train and/or drive train characteristic monitor to eliminate the possibility of loss of control of the load following a single point failure in a drive train.

[0093] As such, and referring to figure 5, the hoist 500 comprises two discrete and redundant drive trains 510 and 505. Each drive train 505 and 510 is independently operatively coupled to a lifting mechanism in the form of a rotating drum 130, and each drive train 505 and 510 is individually capable of arresting and holding the full rated load of the hoist 500.

[0094] Each of the drive trains 510 and 505 comprises a prime mover, preferably in the form of an electric motor 110, gear reducer 115, and attendant braking mechanism in the form of a failsafe brake 105. Each of the drive trains 510 and 505 further comprises a tachometer 315 or device for monitoring the current of the motor 110. It is envisaged that each of the motors 110 will be designed for lifting half of the rated load of

the hoist 500, however each of the failsafe brakes 105 will preferably be configured for holding the entire rated load of the hoist 500 working through the gear reducer 115.

[0095] In this way, each of the failsafe brake 105 need not be rated to the full load of the hoist. Further, should there be a single point failure in the first drive train 505, for example, the second drive train 510 will be able to fully support and control the load.

[0096] In addition, it is envisaged that a hoist 500 according to the invention will preferably be provided with a detection mechanism 600.

[0097] Furthermore, in addition to there being a redundant drive train, and **referring specifically now to figure 6**, the hoist 500 further comprises a detection mechanism 600 as will be described in more detail below. In the embodiments shown in figure 6, the detection mechanism 600 is a controller, referred to as a drive train characteristic monitor 605 which, as will be described below, in combination with the redundant drive train completely reduces, and preferably eliminates the possibility of loss of control of the load following a single point failure in a drive train.

[0098] Specifically, by virtue of the mechanical couplings between the dual drive trains 510 and 505, each of the motors 110 will rotate synchronously with each other.

[0099] However, should there be a failure in either drive train 510 or 505, the motors 110 would become asynchronous and therefore exhibit differing motor characteristics.

[0100] Such motor characteristics may comprise differing rotational speed, frequency or differing stator current waveforms. The rotational speed or stator waveforms are monitored by the drive train characteristic monitor 605 so as to detect when the motors 110 become asynchronous, being indicative of a single point failure. For example, the drive train characteristic monitor 605 can measure the rotational speed of each motor 110 by receiving the outputs from tachometers 315. It will be appreciated that monitoring the motor characteristic of rotational velocity can be measured at any point along the drive train by making use of the appropriate rotational velocity is multiplied by the gearing factors. In this way, monitoring of, for example, shaft speeds along the drive train before and after the gear reducer 115 can be regarded as monitoring of the rotational velocity of the motor 110 of the drive train.

[0101] Furthermore, the drive train characteristic monitor 605 can monitor the stator current waveforms of the motors 110 by appropriate electrical coupling to each motor 110, and with the use of appropriate sensors. The detection of the differing stator current

waveforms may be detected by detecting differences in magnitude, frequency or phase using the appropriate analogue or digital circuit.

[0102] Once such detection has been made, the drive train characteristic monitor 605 is adapted to take appropriate action, such as by activating both of the failsafe brakes 105, or at least one of the failsafe brakes 105. It is envisaged that the drive train characteristic monitor 605 can be configured for detecting which of the drive trains 510 and 505 have incurred a single point failure, and actuating the failsafe brakes 105 on the drive train that has not incurred the failure.

[0103] The configuration of the hoist 500 eliminates the possibility of loss of control of the load following a single point failure in a drive train of the hoist 500. To reiterate, the hoist 500 comprises dual drive trains 510 and 505, each drive train 510, 505, in isolation, being sufficiently rated to arrest and hold the rated load of the hoist 500. Furthermore, the drive train characteristic monitor 605 continually monitors the symmetry of the drive trains during operation such that soon as loss of symmetry is detected, the drive train characteristic monitor 605 is able to make the hoist 500 safe by actuation of the failsafe brake(s) 105.

[0104] Referring now to figure 7, there is shown a perspective mechanical schematic of the hoist 500 of a preferred embodiment. Specifically, the hoist 500 shows the dual motors 110 operably coupled to the gear reducers 115 to form drive trains 510 and 505.

[0105] Furthermore, the hoist 500 comprises the lifting means or lifting mechanism 130, taking the form of a rotating drum. Wrapped about the lifting means 130 is a lifting medium 135, preferably taking the form of flexible steel wire ropes. An alternative embodiment (not shown) it is envisaged that the lifting medium 135 could be a wide variety of alternative configurations, shapes and materials, including chains, ropes, or the like. It is further envisaged that in an alternative embodiment (not shown) the lifting mechanism need not necessarily be a rotating drum, but could also be of a wide variety of configurations and shapes, including a frame, . In an alternative embodiment (not shown) the lifting mechanism 130 need not necessarily pull upwardly on an item to be lifted, but can be configured to push the item to be lifted from below.

Detection mechanism

[0106] It is envisaged that the detection mechanism 600 of the hoist 500 can be electrically operated, or mechanically operated. However, the detection mechanism 600 will preferably comprise a detection arrangement 700 configured for detecting

asymmetry in the drive trains 510 and 505, as well as an actuation arrangement 800 that is configured for actuating a braking mechanism, such as the failsafe brakes 105, in the event of detection of asymmetry in the drive trains.

Electronically controlled

- 5 **[0107]** In an electrically or electronically operated variant, it is envisaged that the detection mechanism 600 will comprise a controller 605. The controller 605 will preferably include a transmitter (not shown) configured for transmitting an actuation signal and other signals, and a receiver (not shown) configured for receiving signals, such as signals generated by sensors and/or transducers as described above. In this
- 10 regard, the controller 605 will preferably be operatively connected to sensors to receive signals from them, as well as to the failsafe brakes 105 in order to actuate them if required.
- 15 **[0108]** The controller 605 will preferably also comprise a processor (not shown) for processing information according to a set of instructions, and digital storage media (not shown) configured for storing instructions, preferably in the form of software. The instructions are configured for instructing the processor to receive signals from the sensors that are indicative of motion in each of the drive trains as discussed above, and compare the received signals from the sensors in real-time to detect asymmetry in the drive trains. In this sense, the controller 605 acts as the detection arrangement 700.
- 20 **[0109]** The instructions are preferably also configured for generating an actuation signal depending on the result of the comparison of the received signals from the sensors, and transmitting the actuation signal to at least one, and preferably both of the failsafe brake 105 to prevent loss of control of the load. It will be appreciated that in this embodiment, the controller 605 acts as the actuation arrangement 800.
- 25 **[0110]** It is envisaged that in receiving signals from the sensors, sufficient information can be received to be able to determine in which of the drive trains a failure has occurred, and an actuation signal generated and transmitted to the failsafe brake 105 in the drive train in which failure has not occurred. An example of factors that could be checked to determine this include power usage and the electric motor, loss of strain
- 30 in a drive train, or the like. However, in a preferred embodiment, the actuation signal will be transmitted to both of the failsafe brakes 105.

[0111] In a preferred embodiment, it is envisaged that the controller will further be adapted to generate an alert signal as will be discussed below, to inform an operator (not shown) of the detected asymmetry.

Mechanically controlled

5 **[0112]** In another preferred embodiment as **shown in figures 8 – 11**, a mechanically operated detection mechanism 610 is provided. The mechanically operated detection mechanism 610 also comprises a detection arrangement 700 and an actuation arrangement 800.

10 **[0113]** The detection arrangement 700 comprises a linkage 710 extending between each drive train 510 and 505, and which is configured to move in the event of asymmetrical motion in the drive trains.

15 **[0114]** The linkage 710 comprises a fixed member, in the form of a shaft 720, that is securely connected to a first drive train by fixing screws 722 to rotate synchronously with the first drive train. The linkage 710 further comprises a moving member 730. The moving member 730 is generally hollow and is engaged with the second drive train by a key arrangement 732. In this way, the moving member 730 is configured to move rotationally synchronously with the second drive train, while being movable longitudinally along the second drive train.

20 **[0115]** The shaft 720 and the moving member 730 threaded engaged with each other at a threaded interface 740. When the shaft 720 and the moving member 730 are rotating at the same angular velocity, they will remain the same relative distance from each other. However, when the shaft 720 and the moving member 730 rotate at different angular velocities, the threaded interface 740 will cause the moving member 732 move either further away from or closer to the shaft 720. The moving member 732 is allowed
25 to move in a longitudinal direction along the second drive train by the key arrangement 732. It is envisaged that in alternative embodiments (not shown) the shaft and the moving member 730 can engage with each other at alternative interface types rather than a threaded interface. One example can be a bayonet – type interface, while another can be a helical arrangement. Further, alternative arrangements are possible that allow
30 for longitudinal movement of the moving member. Some examples of such arrangements include bushing arrangements, lever type arrangements or the like.

[0116] It will be appreciated by those skilled in the art that in alternative embodiments (not shown), the linkage 710 need not necessarily include a moving

member. For example, a differential or planetary gear system can be used that causes movement of a detection member (not shown) when the rotational movement of the drive trains 510 and 505 is asymmetrical or asynchronous.

[0117] The moving member 730 preferably comprises a sensing formation in the form of a flange 734. The flange 734 is configured to be detectable by an actuation sensor 810 that is part of the actuation arrangement 800. In a preferred embodiment, the sensor is a proximity sensor, being able to detect the presence of the flange 734. It is envisaged that in alternative embodiments (not shown) a wide variety of sensors can be used to detect movement of the sensing formation, including laser distance sensors, light sensors, ultrasound distance sensors, magnetic sensors, electromagnetic induction sensors, or the like.

[0118] In any event, when movement of the moving member 730 causes movement of the flange 734, the actuation sensor 810 will detect that movement has occurred. Once such movement has been detected, the actuation sensor 810 will preferably send an actuation signal. The actuation signal can be sent to a controller as described above that will in turn actuate the failsafe brakes 105. Alternatively, the actuation signal can trip a switch or relay to cause actuation of the failsafe brakes 105.

[0119] It is envisaged that the detection mechanism 600 need not necessarily actuate the failsafe brakes 105 when there is the slightest amount of asynchronous movement between the drive trains 510 and 505. Instead, it is envisaged that the detection mechanism 600 could actuate the failsafe brakes only after the drive trains are a few rotations out of synchronisation.

In use

[0120] In use, the controller or drive train characteristic monitor 605 is configured for carrying out the method of operating the electromechanical hoist 500 as a computer implemented method for reducing, and preferably eliminating the possibility of loss of control of the load following a single point failure in a drive train. As discussed above, the controller initially carries out the step of detecting asymmetry between the respective motors 110 and/or drive trains 510 and 505. In order to carry out the step, the controller signals from appropriately located sensors, such as those configured for detecting and signalling one or more of rotational velocity of the drive trains, motor stator current of a motor in each of the drive trains; frequency of the drive trains, frequency of the motor stator current; magnitude of the motor stator current, and strain in the drive trains.

[0121] In this regard, the relevant sensors could include any known sensors including but not limited to optical sensors, magnetic sensors, current sensors, voltage sensors, frequency sensors and strain gauges. It is also anticipated that the relevant sensors can be analogue or digital type sensors. It is anticipated that the relevant sensors may be configured for transmitting signals over a wired or wireless network to the drive train characteristic monitor 605.

[0122] As alluded to above, detecting asymmetry may comprise monitoring rotational speed difference, a motor stator current characteristic difference or the like. The motor stator current characteristic being frequency characteristic, phase characteristic, magnitude characteristic or the like.

[0123] Upon detecting the asymmetry, the method further comprises the step of taking appropriate action to make the hoist 500 safe, such as by actuating both brakes. In addition, it is envisaged that the drive train characteristic monitor 605 can be configured to generate an alert signal. Such an alert signal can be sent wirelessly or through a network to an operator, preferably for display on a display unit such as a monitor or screen.

[0124] In addition to the use of an electronically based controller such as the drive train characteristic monitor 605 described above, it is envisaged that the electronically controlled

Interpretation

Composite items

[0125] As described herein, 'a computer implemented method' should not necessarily be inferred as being performed by a single computing device such that the steps of the method may be performed by more than one cooperating computing devices.

[0126] Similarly objects as used herein such as 'web server', 'server', 'client computing device', 'computer readable medium' and the like should not necessarily be construed as being a single object, and may be implemented as a two or more objects in cooperation, such as, for example, a web server being construed as two or more web servers in a server farm cooperating to achieve a desired goal or a computer readable medium being distributed in a composite manner, such as program code being provided on a compact disk activatable by a license key downloadable from a computer network.

Wireless:

[0127] The invention may be embodied using devices conforming to other network standards and for other applications, including, for example other WLAN standards and other wireless standards. Applications that can be accommodated include IEEE 802.11 wireless LANs and links, and wireless Ethernet.

[0128] In the context of this document, the term “wireless” and its derivatives may be used to describe circuits, devices, systems, methods, techniques, communications channels, etc., that may communicate data through the use of modulated electromagnetic radiation through a non-solid medium. The term does not imply that the associated devices do not contain any wires, although in some embodiments they might not. In the context of this document, the term “wired” and its derivatives may be used to describe circuits, devices, systems, methods, techniques, communications channels, etc., that may communicate data through the use of modulated electromagnetic radiation through a solid medium. The term does not imply that the associated devices are coupled by electrically conductive wires.

Processes:

[0129] Unless specifically stated otherwise, as apparent from the following discussions, it is appreciated that throughout the specification discussions utilizing terms such as “processing”, “computing”, “calculating”, “determining”, “analysing” or the like, refer to the action and/or processes of a computer or computing system, or similar electronic computing device, that manipulate and/or transform data represented as physical, such as electronic, quantities into other data similarly represented as physical quantities.

Processor:

[0130] In a similar manner, the term “processor” may refer to any device or portion of a device that processes electronic data, e.g., from registers and/or memory to transform that electronic data into other electronic data that, e.g., may be stored in registers and/or memory. A “computer” or a “computing device” or a “computing machine” or a “computing platform” may include one or more processors.

[0131] The methodologies described herein are, in one embodiment, performable by one or more processors that accept computer-readable (also called machine-readable) code containing a set of instructions that when executed by one or more of the processors carry out at least one of the methods described herein. Any processor

capable of executing a set of instructions (sequential or otherwise) that specify actions to be taken are included. Thus, one example is a typical processing system that includes one or more processors. The processing system further may include a memory subsystem including main RAM and/or a static RAM, and/or ROM.

5 *Computer-Readable Medium:*

[0132] Furthermore, a digital storage media or computer-readable carrier medium may form, or be included in a computer program product. A computer program product can be stored on a computer usable carrier medium, the computer program product comprising a computer readable program means for causing a processor to perform a
10 method as described herein.

Networked or Multiple Processors:

[0133] In alternative embodiments, the one or more processors operate as a standalone device or may be connected, e.g., networked to other processor(s), in a networked deployment, the one or more processors may operate in the capacity of a
15 server or a client machine in server-client network environment, or as a peer machine in a peer-to-peer or distributed network environment. The one or more processors may form a web appliance, a network router, switch or bridge, or any machine capable of executing a set of instructions (sequential or otherwise) that specify actions to be taken by that machine.

[0134] Note that while some diagram(s) only show(s) a single processor and a single memory that carries the computer-readable code, those in the art will understand that many of the components described above are included, but not explicitly shown or described in order not to obscure the inventive aspect. For example, while only a single machine is illustrated, the term "machine" shall also be taken to include any collection of
20 machines that individually or jointly execute a set (or multiple sets) of instructions to perform any one or more of the methodologies discussed herein.

Additional Embodiments:

[0135] Thus, one embodiment of each of the methods described herein is in the form of a computer-readable carrier medium carrying a set of instructions, e.g., a computer
30 program that are for execution on one or more processors. Thus, as will be appreciated by those skilled in the art, embodiments of the present invention may be embodied as a method, an apparatus such as a special purpose apparatus, an apparatus such as a data processing system, or a computer-readable carrier medium. The computer-

readable carrier medium carries computer readable code including a set of instructions that when executed on one or more processors cause a processor or processors to implement a method. Accordingly, aspects of the present invention may take the form of a method, an entirely hardware embodiment, an entirely software embodiment or an embodiment combining software and hardware aspects. Furthermore, the present invention may take the form of carrier medium (e.g., a computer program product on a computer-readable storage medium) carrying computer-readable program code embodied in the medium.

Carrier Medium:

[0136] The software may further be transmitted or received over a network via a network interface device. While the carrier medium is shown in an example embodiment to be a single medium, the term “carrier medium” should be taken to include a single medium or multiple media (e.g., a centralized or distributed database, and/or associated caches and servers) that store the one or more sets of instructions. The term “carrier medium” shall also be taken to include any medium that is capable of storing, encoding or carrying a set of instructions for execution by one or more of the processors and that cause the one or more processors to perform any one or more of the methodologies of the present invention. A carrier medium may take many forms, including but not limited to, non-volatile media, volatile media, and transmission media.

Implementation:

[0137] It will be understood that the steps of methods discussed are performed in one embodiment by an appropriate processor (or processors) of a processing (i.e., computer) system executing instructions (computer-readable code) stored in storage. It will also be understood that the invention is not limited to any particular implementation or programming technique and that the invention may be implemented using any appropriate techniques for implementing the functionality described herein. The invention is not limited to any particular programming language or operating system.

Means For Carrying out a Method or Function

[0138] Furthermore, some of the embodiments are described herein as a method or combination of elements of a method that can be implemented by a processor of a processor device, computer system, or by other means of carrying out the function. Thus, a processor with the necessary instructions for carrying out such a method or element of a method forms a means for carrying out the method or element of a method.

Furthermore, an element described herein of an apparatus embodiment is an example of a means for carrying out the function performed by the element for the purpose of carrying out the invention.

Connected

5 **[0139]** Similarly, it is to be noticed that the term connected, when used in the claims, should not be interpreted as being limitative to direct connections only. Thus, the scope of the expression a device A connected to a device B should not be limited to devices or systems wherein an output of device A is directly connected to an input of device B. It means that there exists a path between an output of A and an input of B which may be a
10 path including other devices or means. “Connected” may mean that two or more elements are either in direct physical or electrical contact, or that two or more elements are not in direct contact with each other but yet still co-operate or interact with each other.

Embodiments:

15 **[0140]** Reference throughout this specification to “one embodiment” or “an embodiment” means that a particular feature, structure or characteristic described in connection with the embodiment is included in at least one embodiment of the present invention. Thus, appearances of the phrases “in one embodiment” or “in an
20 embodiment” in various places throughout this specification are not necessarily all referring to the same embodiment, but may. Furthermore, the particular features, structures or characteristics may be combined in any suitable manner, as would be apparent to one of ordinary skill in the art from this disclosure, in one or more embodiments.

25 **[0141]** Similarly it should be appreciated that in the above description of example embodiments of the invention, various features of the invention are sometimes grouped together in a single embodiment, figure, or description thereof for the purpose of streamlining the disclosure and aiding in the understanding of one or more of the various inventive aspects. This method of disclosure, however, is not to be interpreted as reflecting an intention that the claimed invention requires more features than are
30 expressly recited in each claim. Rather, as the following claims reflect, inventive aspects lie in less than all features of a single foregoing disclosed embodiment. Thus, the claims following the Detailed Description of Specific Embodiments are hereby expressly incorporated into this Detailed Description of Specific Embodiments, with each claim standing on its own as a separate embodiment of this invention.

[0142] Furthermore, while some embodiments described herein include some but not other features included in other embodiments, combinations of features of different embodiments are meant to be within the scope of the invention, and form different embodiments, as would be understood by those in the art. For example, in the following claims, any of the claimed embodiments can be used in any combination.

Specific Details

[0143] In the description provided herein, numerous specific details are set forth. However, it is understood that embodiments of the invention may be practiced without these specific details. In other instances, well-known methods, structures and techniques have not been shown in detail in order not to obscure an understanding of this description.

Terminology

[0144] In describing the preferred embodiment of the invention illustrated in the drawings, specific terminology will be resorted to for the sake of clarity. However, the invention is not intended to be limited to the specific terms so selected, and it is to be understood that each specific term includes all technical equivalents which operate in a similar manner to accomplish a similar technical purpose. Terms such as "forward", "rearward", "radially", "peripherally", "upwardly", "downwardly", and the like are used as words of convenience to provide reference points and are not to be construed as limiting terms.

Different Instances of Objects

[0145] As used herein, unless otherwise specified the use of the ordinal adjectives "first", "second", "third", etc., to describe a common object, merely indicate that different instances of like objects are being referred to, and are not intended to imply that the objects so described must be in a given sequence, either temporally, spatially, in ranking, or in any other manner.

Comprising and Including

[0146] In the claims which follow and in the preceding description of the invention, except where the context requires otherwise due to express language or necessary implication, the word "comprise" or variations such as "comprises" or "comprising" are used in an inclusive sense, i.e. to specify the presence of the stated features but not to

preclude the presence or addition of further features in various embodiments of the invention.

[0147] Any one of the terms: including or which includes or that includes as used herein is also an open term that also means including at least the elements/features that follow the term, but not excluding others. Thus, including is synonymous with and means comprising.

Scope of Invention

[0148] Thus, while there has been described what are believed to be the preferred embodiments of the invention, those skilled in the art will recognize that other and further modifications may be made thereto without departing from the spirit of the invention, and it is intended to claim all such changes and modifications as fall within the scope of the invention. For example, any formulas given above are merely representative of procedures that may be used. Functionality may be added or deleted from the block diagrams and operations may be interchanged among functional blocks. Steps may be added or deleted to methods described within the scope of the present invention.

[0149] Although the invention has been described with reference to specific examples, it will be appreciated by those skilled in the art that the invention may be embodied in many other forms.

Chronological order

[0150] For the purpose of this specification, where method steps are described in sequence, the sequence does not necessarily mean that the steps are to be carried out in chronological order in that sequence, unless there is no other logical manner of interpreting the sequence.

Markush groups

[0151] In addition, where features or aspects of the invention are described in terms of Markush groups, those skilled in the art will recognise that the invention is also thereby described in terms of any individual member or subgroup of members of the Markush group.

Industrial Applicability

[0152] It is apparent from the above, that the arrangements described are applicable to the rigging and entertainment industries.

Claims

1. An electromechanical hoist for eliminating the possibility of loss of control of the load following a single point failure in a drive train, the hoist comprising:

a) a lifting mechanism,

5 b) a plurality of drive trains, each drive train being independently operatively coupled to the lifting mechanism, wherein each drive train comprises

i) a gear reducer;

ii) a prime mover rated for providing a lifting force to the lifting mechanism via the gear reducer that is lower than the rated load of the lifting mechanism;

10 iii) a braking mechanism that is rated for generating a braking force via the gear reducer at least equal to the rated load of the lifting mechanism;

c) a drive train characteristic monitor configured for detecting a drive train characteristic at the end of each drive train distal to the lifting mechanism; and

15 d) an actuation arrangement configured for actuating at least one or more braking mechanisms in the event of the detection of a threshold level of asymmetry in said plurality of drive trains to thereby eliminate the possibility of loss of control of the load following a single point failure in either of the drive trains.

2. An electromechanical hoist as claimed in claim 1, wherein the prime mover is rated for providing a lifting force to the lifting mechanism via the gear reducer that is substantially
20 half of the rated load of the lifting mechanism.

3. An electromechanical hoist as claimed in any one of claims 1 to 2, wherein the drive train characteristic monitor is adapted to monitor rotational speed of the drive trains.

4. An electromechanical hoist as claimed in claim 2, wherein the drive train characteristic monitor comprises a tachometer.

25 5. An electromechanical hoist as claimed in claim 4, wherein the drive train characteristic monitor is operably coupled to the tachometer so as to be adapted for determining the rotational velocity of each respective drive train.

30 6. An electromechanical hoist as claimed in any one of claims 1 to 5, wherein the prime mover is coupled to the gear reducer on an opposed side of the gear reducer from the lifting mechanism.

7. An electromechanical hoist as claimed in any one of claims 1 to 6, wherein the braking mechanism is coupled to the prime mover on an opposed side of the prime mover from the gear reducer.
8. An electromechanical hoist as claimed in any one of claims 1 to 7, wherein the drive train characteristic monitor is operably coupled to a rotational control circuit of each of the respective prime movers.
9. An electromechanical hoist as claimed in claim 8, wherein, in use, the drive train characteristic monitor is adapted to stop the rotation of both motors upon detecting asymmetry between the respective prime movers.
10. **An electromechanical hoist for eliminating the possibility of loss of control of the load following a single point failure in a drive train, the hoist comprising:**
 - a) a lifting mechanism having a rated load;
 - b) a plurality of drive trains, each drive train being independently operatively coupled to the lifting mechanism, wherein each drive train comprises
 - i) a gear reducer;
 - ii) a prime mover rated for providing a lifting force to the lifting mechanism via the gear reducer that is lower than the rated load of the lifting mechanism;
 - iii) a braking mechanism that is rated for generating a braking force via the gear reducer at least equal to the rated load of the lifting mechanism; and
 - iv) a drive train characteristic monitor configured for detecting a drive train characteristic of each drive train; and
 - c) a controller configured for controlling operation of the braking mechanism in the event of detected asymmetry in the drive trains;
 - d) wherein the drive train characteristic monitors and control system are configured for eliminating the possibility of loss of control of the load following a single point failure in either of the drive trains.
11. An electromechanical hoist as claimed in claim 10, wherein the prime mover is rated for providing a lifting force to the lifting mechanism via the gear reducer that is substantially half of the rated load of the lifting mechanism.

12. An electromechanical hoist as claimed in any one of claims 10 to 11, wherein the drive train characteristic monitor on each drive train is configured to detect a drive train characteristic at the end of each drive train.

5 13. An electromechanical hoist as claimed in any one of claims 10 to 11, wherein the drive train characteristic monitor is configured to detect a drive train characteristic at the end of each drive train distal to the lifting mechanism.

14. An electromechanical hoist as claimed in any one of claims 10 to 13, wherein the gear reducer is connected to the lifting mechanism.

10 15. An electromechanical hoist as claimed in any one of claims 10 to 13, wherein the prime mover is connected to the gear reducer.

16. An electromechanical hoist as claimed in any one of claims 10 to 13, wherein the braking mechanism is connected to the prime mover.

15 **17. A method of operating an electromechanical hoist for eliminating the possibility of loss of control of a load following a single point failure in a drive train, the method comprising the steps of:**

a) providing a hoist comprising

i) a lifting mechanism,

ii) a plurality of drive trains, each drive train being independently operatively coupled to the lifting mechanism, wherein each drive train comprises

20 (1) a gear reducer;

(2) a prime mover rated for providing a lifting force to the lifting mechanism via the gear reducer that is lower than the rated load of the lifting mechanism;

(3) a braking mechanism that is rated for generating a braking force via the gear reducer at least equal to the rated load of the lifting mechanism;

25 ii) a drive train characteristic monitor configured for detecting a drive train characteristic at an end of each drive train distal to the lifting mechanism; and

iii) an actuation arrangement configured for actuating at least one or more of the braking mechanisms;

b) detecting asymmetry between respective drive trains; and

- c) actuating the braking mechanisms to thereby eliminate the possibility of loss of control of the load following a single point failure in either of the drive trains.

18. A method as claimed in claim 17, wherein each of the prime movers is rated for providing a lifting force to the lifting mechanism via the gear reducer that is substantially half the
5 rated load of the lifting mechanism.

19. A method as claimed in any one of claims 17 to 18, wherein the step of detecting asymmetry comprises the step of

- a) monitoring a rotational speed difference in each drive train.

20. A method as claimed in any one of claims 17 to 19, further comprising the step of

- 10 a) stopping the rotation of a motor in each drive train upon detecting asymmetry.

21. A method as claimed in any one of claims 17 to 20, wherein the method further comprises the step of

- a) generating an alert signal.

22. A hoist comprising

- 15 a) a lifting mechanism,

- b) a plurality of drive trains, each drive train being independently operatively coupled to the lifting mechanism, wherein each drive train comprises

- i) a gear reducer coupled to the lifting mechanism;

- 20 ii) at least one prime mover coupled to the gear reducer on an opposed side of the gear reducer from the lifting mechanism, the prime mover being rated for providing a lifting force to the lifting mechanism via the gear reducer that is lower than the rated load of the lifting mechanism;

- 25 iii) a braking mechanism coupled to the prime mover on an opposed side of the prime mover from the gear reducer, the braking mechanism being rated for generating a braking force via the gear reducer at least equal to the rated load of the lifting mechanism; and

- c) a detection mechanism comprising

- i) a detection arrangement configured for detecting asymmetry in the rotation of the drive trains at the end of each drive train opposed to the lifting mechanism,

- ii) an actuation arrangement configured for actuating both braking mechanisms in the event of the detection of a threshold level of asymmetry in said plurality of drive trains.

23. A hoist as claimed in claim 22, wherein the prime movers are electric motors.

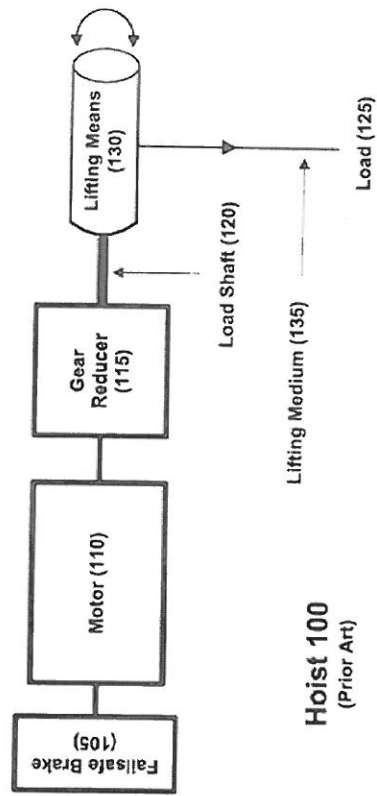


Figure 1

(PRIOR ART)

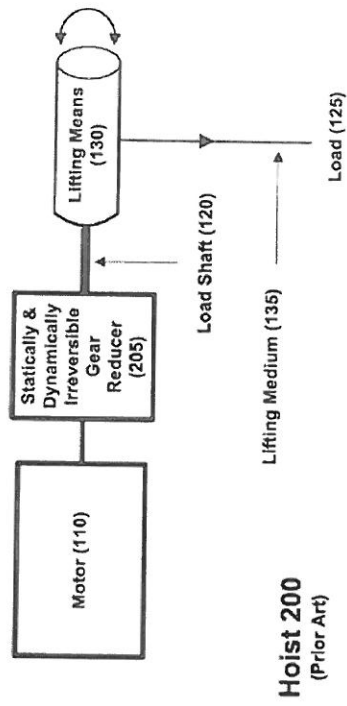


Figure 2
(PRIOR ART)

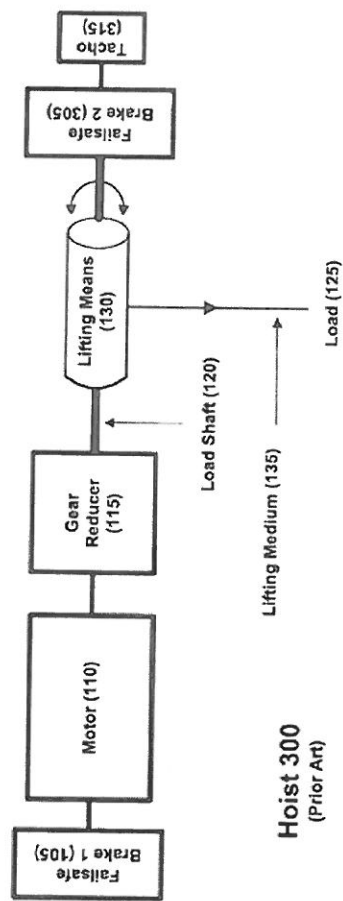
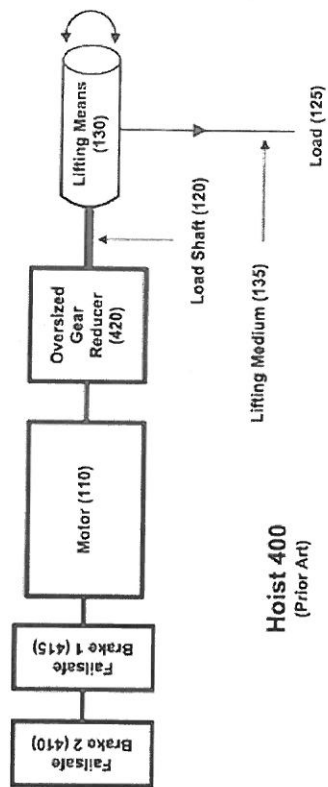


Figure 3
(PRIOR ART)



Hoist 400
(Prior Art)

Figure 4
(PRIOR ART)

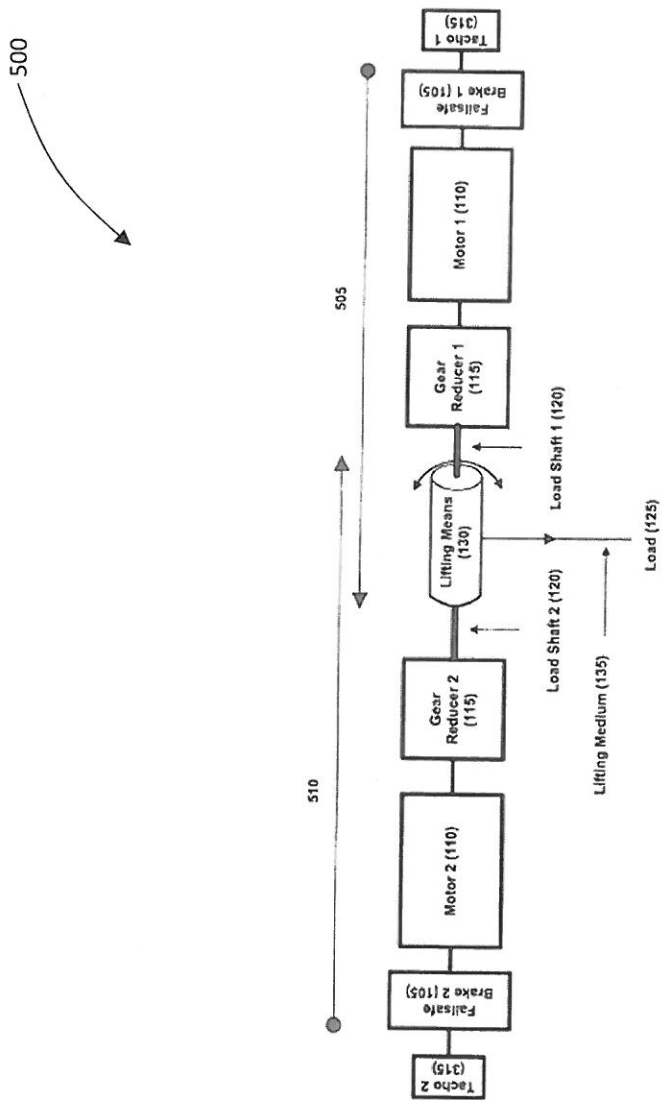


Figure 5

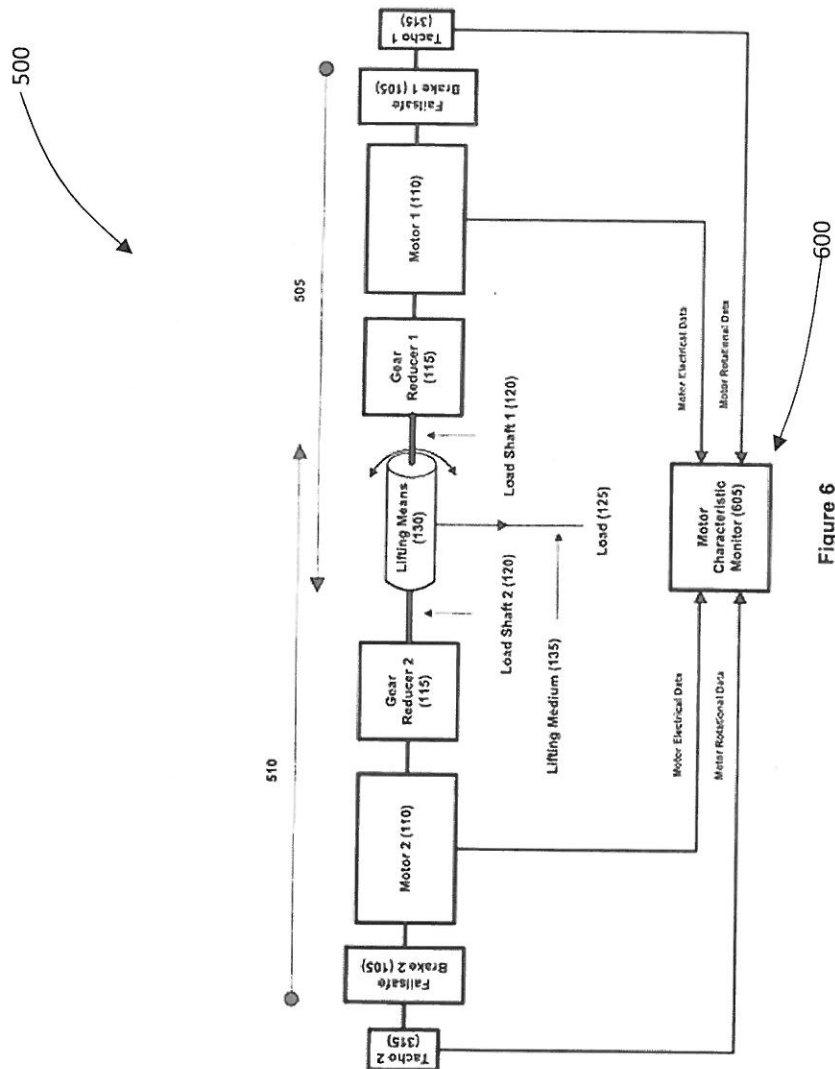


Figure 6

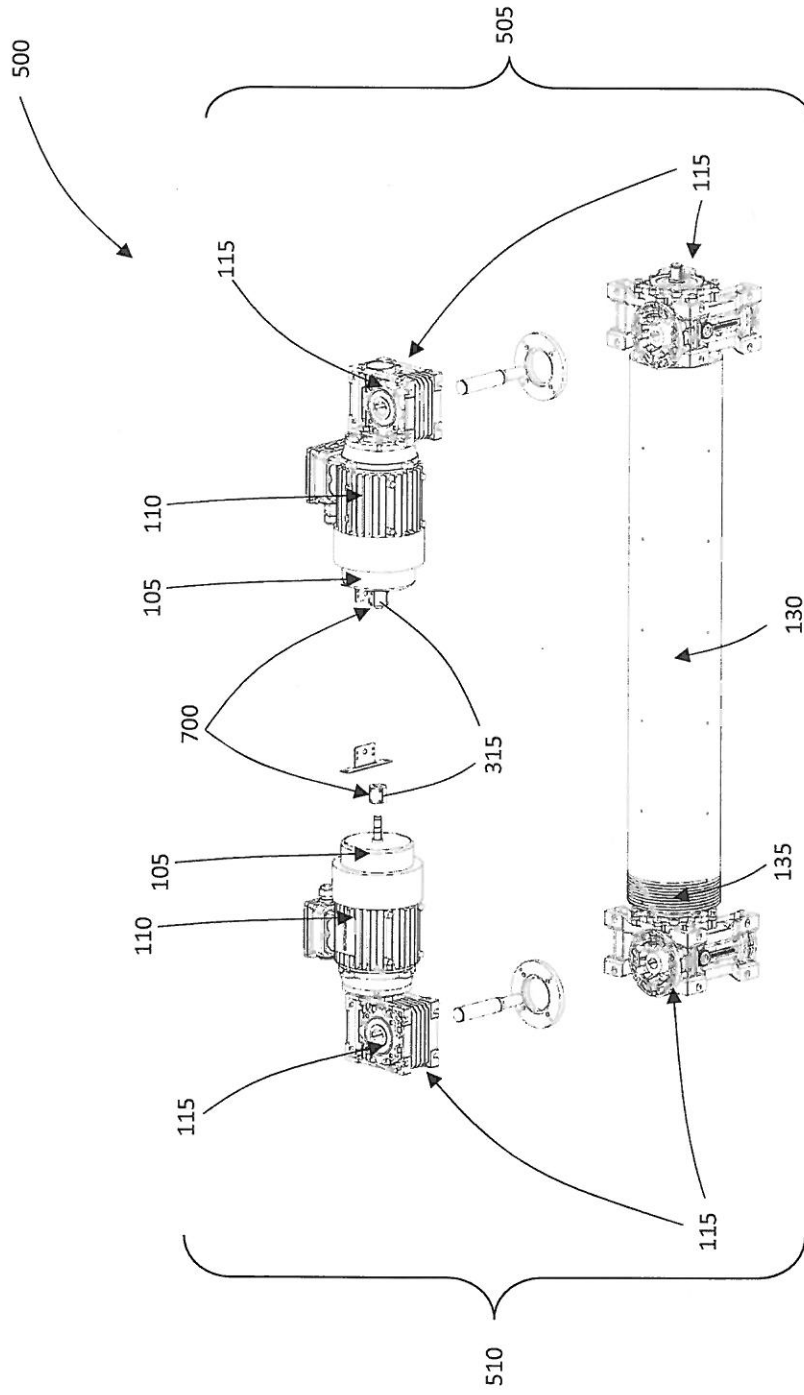


Figure 7

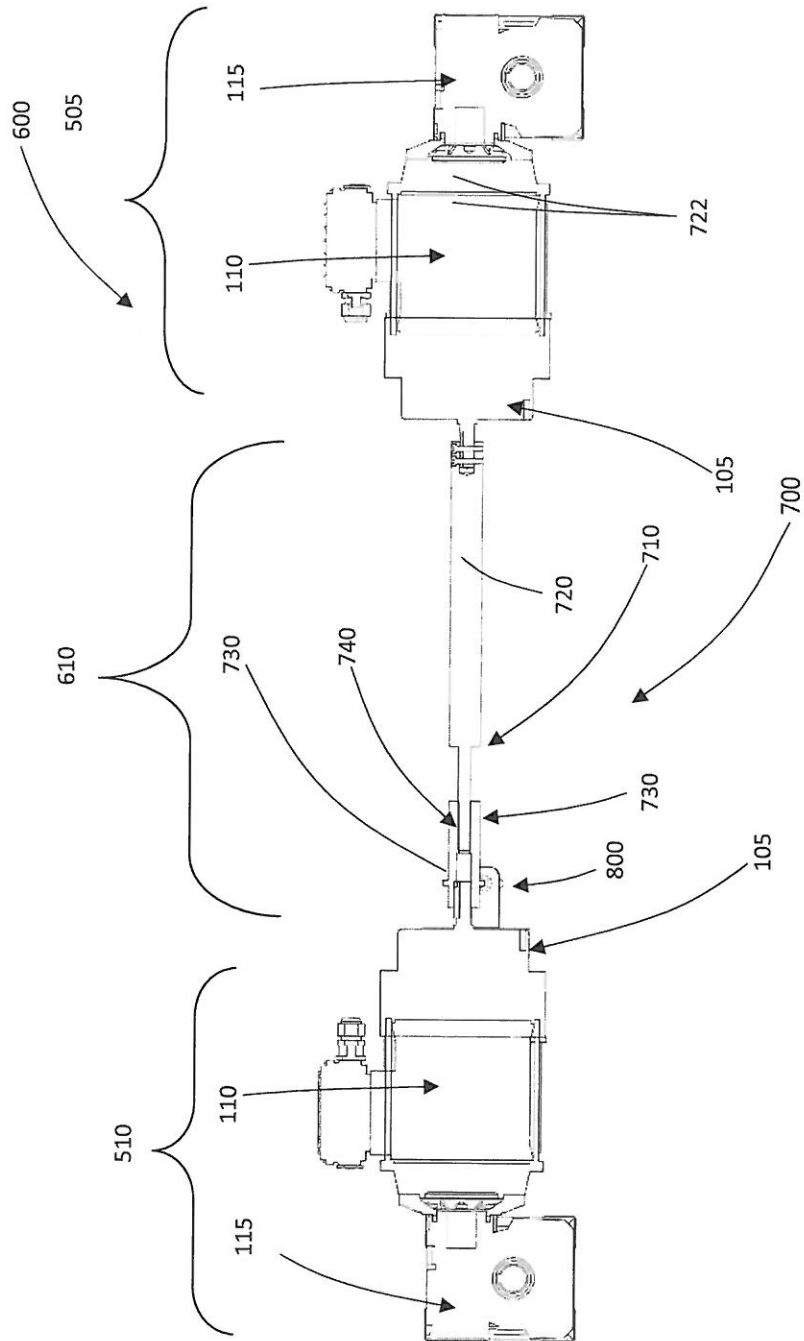


Figure 8

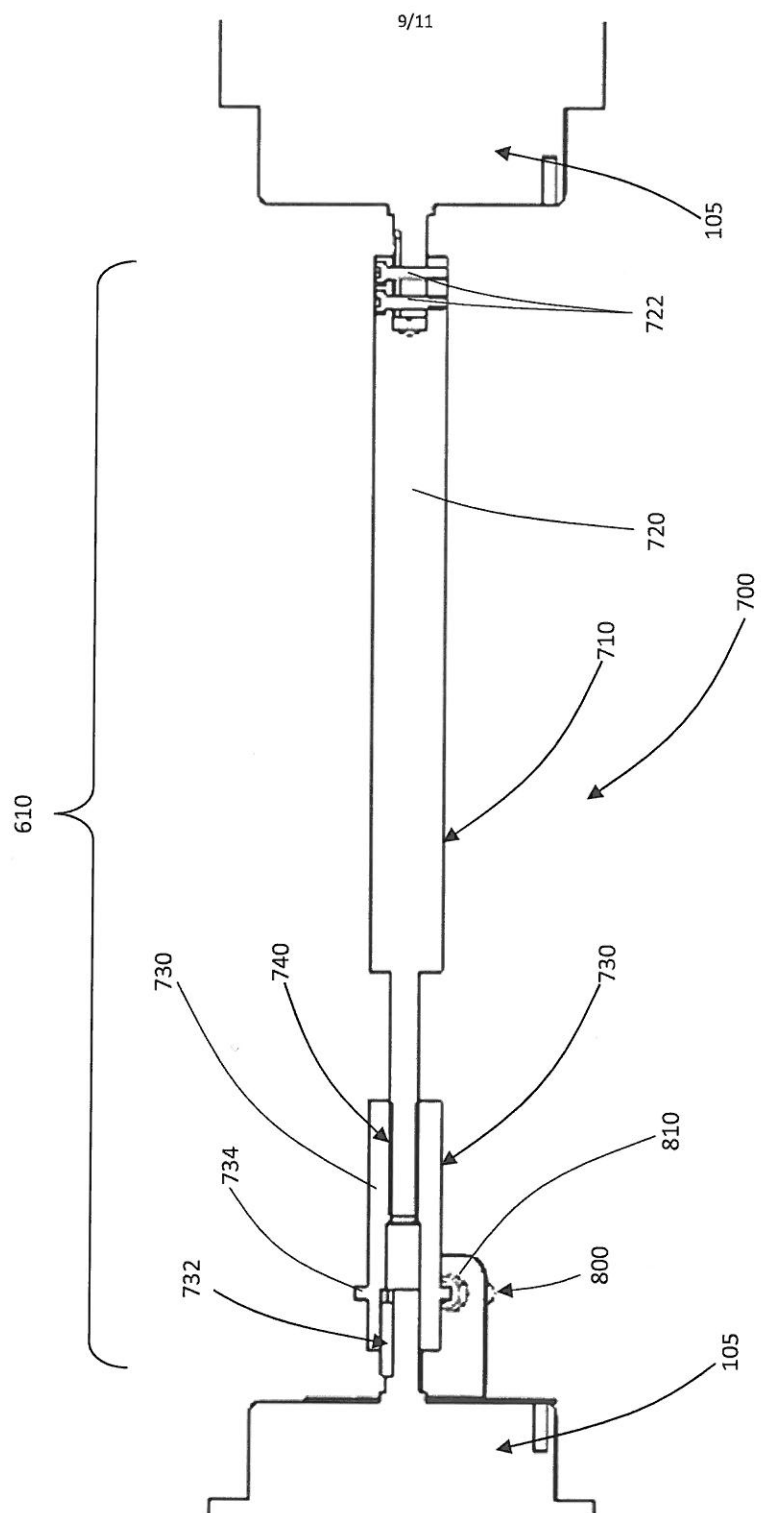


Figure 9

