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(54) **BEAM CLIMBER ACTIVE BRAKE HEALTH MONITORING SYSTEM**

(57) An elevator system (101) including: an elevator car (103) configured to travel through an elevator shaft (117); a first guide beam (111a, 111b) extending vertically through the elevator shaft (117), the first guide beam (11a, 111b) including a first surface (112a) and a second surface (112b) opposite the first surface (112a); a beam climber system (130) configured to move the elevator car (103) through the elevator shaft (117), the beam climber system (130) including: a first wheel (134a, 134b) in contact with the first surface (112a); and a first electric motor (132a, 132b) configured to rotate the first wheel (134a, 134b); a first motor brake (137a, 137b) mechanically connected to the first electric motor (132a, 132b), the first motor brake (137a, 137b) configured to slow the elevator car (103); and a brake condition based monitoring system (200) configured to detect when the first motor brake (137a, 137b) is dragging.

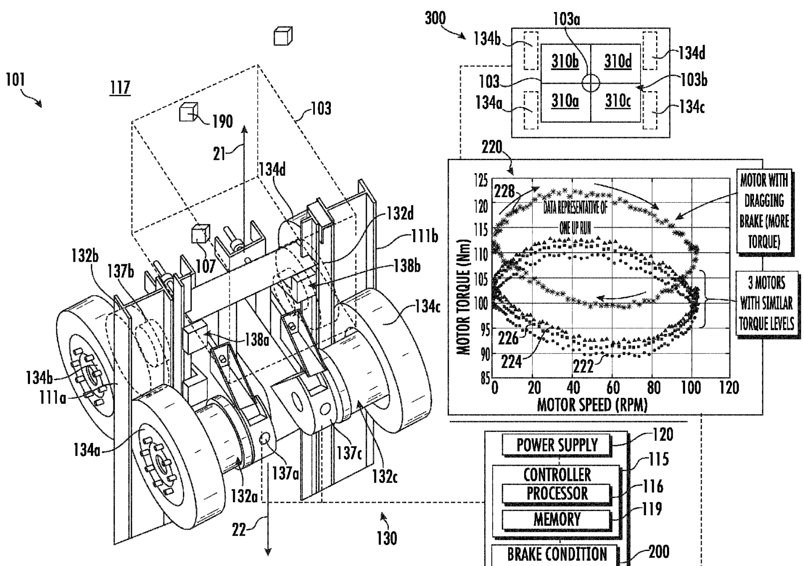

FIG. 2

EP 3 945 054 A1

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Description

BACKGROUND

[0001] The subject matter disclosed herein relates generally to the field of elevator systems, and specifically to a method and apparatus for detecting brake health on brakes of propulsion systems for an elevator car.

[0002] Elevator cars are conventionally operated by ropes and counter weights, which typically only allow one elevator car in an elevator shaft at a single time.

BRIEF SUMMARY

[0003] According to an embodiment, an elevator system is provided. The elevator system including: an elevator car configured to travel through an elevator shaft; a first guide beam extending vertically through the elevator shaft, the first guide beam including a first surface and a second surface opposite the first surface; a beam climber system configured to move the elevator car through the elevator shaft, the beam climber system including: a first wheel in contact with the first surface; and a first electric motor configured to rotate the first wheel; a first motor brake mechanically connected to the first electric motor, the first motor brake configured to slow the elevator car; and a brake condition based monitoring system configured to detect when the first motor brake is dragging.

[0004] In addition to one or more of the features described herein, or as an alternative, further embodiments may include that the brake condition based monitoring system is configured to detect when the first motor brake is dragging based upon at least a torque of the first electric motor.

[0005] In addition to one or more of the features described herein, or as an alternative, further embodiments may include a floor pressure sensor configured to determine a center of gravity of the elevator car, wherein the brake condition based monitoring system is configured to detect when the first motor brake is dragging based upon at least the torque of the first electric motor and the center of gravity.

[0006] In addition to one or more of the features described herein, or as an alternative, further embodiments may include that the brake condition monitoring system is configured to normalize the torque of the first electric motor based on the center of gravity of the elevator car.

[0007] In addition to one or more of the features described herein, or as an alternative, further embodiments may include that the beam climber system further includes: a second wheel in contact with the second surface; a second electric motor configured to rotate the second wheel; and a second motor brake mechanically connected to the second electric motor, the second motor brake configured to slow the elevator car, wherein the brake condition based monitoring system is configured to detect when the second motor brake is dragging.

[0008] In addition to one or more of the features described herein, or as an alternative, further embodiments may include that the brake condition based monitoring system is configured to detect when the second motor brake is dragging based upon at least a torque of the second electric motor.

[0009] In addition to one or more of the features described herein, or as an alternative, further embodiments may include a first guide rail extending vertically through the elevator shaft, wherein the beam climber system further includes: a first guide rail brake operably connected to the first guide rail, wherein the brake condition monitoring system is configured to detect when the first guide rail brake is dragging based upon at least a torque of the first electric motor and the torque of the second electric motor.

[0010] In addition to one or more of the features described herein, or as an alternative, further embodiments may include a second guide beam extending vertically through the elevator shaft, the second guide beam including a first surface of the second guide beam and a second surface of the second guide beam opposite the first surface of the second guide beam, wherein the beam climber system further includes: a second wheel in contact with the second surface of the first guide beam; a second electric motor configured to rotate the second wheel; a second motor brake mechanically connected to the second electric motor, the second motor brake configured to slow the elevator car; a third wheel in contact with the first surface of the second guide beam; a third electric motor configured to rotate the third wheel; a third motor brake mechanically connected to the third electric motor, the third motor brake configured to slow the elevator car; a fourth wheel in contact with the second surface of the second guide beam; a fourth electric motor configured to rotate the fourth wheel; a fourth motor brake mechanically connected to the fourth electric motor, the fourth motor brake configured to slow the elevator car, wherein the brake condition based monitoring system is configured to detect when second motor brake is dragging, detect when the third motor brake is dragging, and detect when the fourth motor brake is dragging.

[0011] In addition to one or more of the features described herein, or as an alternative, further embodiments may include that the brake condition based monitoring system is configured to detect when the second motor brake is dragging based upon at least a torque of the second electric motor.

[0012] In addition to one or more of the features described herein, or as an alternative, further embodiments may include a first guide rail extending vertically through the elevator shaft, wherein the beam climber system further includes: a first guide rail brake operably connected to the first guide rail, wherein the brake condition monitoring system is configured to detect when the first guide rail brake is dragging based upon at least the torque of the first electric motor and the torque of the second electric motor.

[0013] In addition to one or more of the features described herein, or as an alternative, further embodiments may include a second guide rail extending vertically through the elevator shaft, wherein the beam climber system further includes: a second guide rail brake operably connected to the second guide rail, wherein the brake condition monitoring system is configured to detect when the second guide rail brake is dragging based upon at least a torque of the third electric motor and a torque of the fourth electric motor.

[0014] In addition to one or more of the features described herein, or as an alternative, further embodiments may include a floor pressure sensor configured to determine a center of gravity of the elevator car, wherein the brake condition based monitoring system is configured to detect at least one of when the first motor brake is dragging, detect when the second motor brake is dragging, detect when the third motor brake is dragging, or detect when the fourth motor brake is dragging based upon at least the torque of the first electric motor, a torque of the second electric motor, a torque of the third electric motor, a torque of the fourth electric motor, and the center of gravity.

[0015] In addition to one or more of the features described herein, or as an alternative, further embodiments may include that the brake condition monitoring system is configured to normalize the torque of the first electric motor, the second electric motor, the third electric motor, and the fourth electric motor based on the center of gravity of the elevator car.

[0016] According to another embodiment, a method of detecting brake drag within an elevator system is provided. The method including: rotating, using a first electric motor of a beam climber system, a first wheel, the first wheel being in contact with a first surface of a first guide beam that extends vertically through an elevator shaft; moving, using the beam climber system, an elevator car through the elevator shaft when the first wheel of the beam climber system rotates along the first surface of the first guide beam; detecting, using a brake condition based monitoring system, when a first motor brake is dragging.

[0017] In addition to one or more of the features described herein, or as an alternative, further embodiments may include detecting a torque of the first electric motor, wherein the brake condition based monitoring system is configured to detect when the first motor brake is dragging based upon at least a torque of the first electric motor.

[0018] In addition to one or more of the features described herein, or as an alternative, further embodiments may include that detecting a center of gravity of the elevator car, wherein the brake condition based monitoring system is configured to detect when the first motor brake is dragging based upon at least a torque of the first electric motor and the center of gravity.

[0019] In addition to one or more of the features described herein, or as an alternative, further embodiments may include that normalizing the torque of the first electric motor based on the center of gravity of the elevator car.

[0020] In addition to one or more of the features described herein, or as an alternative, further embodiments may include that rotating, using a second electric motor of the beam climber system, a second wheel, the second wheel being in contact with a second surface of the first guide beam; moving, using the beam climber system, the elevator car through the elevator shaft when the first wheel of the beam climber system rotates along the first surface of the first guide beam and the second wheel of the beam climber system rotates along the second surface of the first guide beam; detecting, using the brake condition based monitoring system, at least one of when the first motor brake is dragging or when the second motor brake is dragging.

[0021] In addition to one or more of the features described herein, or as an alternative, further embodiments may include a first guide rail extending vertically through the elevator shaft, wherein the beam climber system further includes a first guide rail brake operably connected to the first guide rail, wherein the method further includes: detecting, using the brake condition monitoring system, when the first guide rail brake is dragging based upon at least a torque of the first electric motor and a torque of the second electric motor.

[0022] According to another embodiment, a method of detecting brake drag within an elevator system is provided. The method including: detecting a load within an elevator car; determining a center of gravity of the elevator car; determining a predicted motor torque of an electric motor of a beam climber assembly during a constant speed of the elevator car; adjusting a motor torque detection range for the electric motor based on the load within the elevator car and the center of gravity; moving the elevator car, using the beam climber system, for an elevator run and recording the motor torque experienced by the electric motor during a constant speed portion of the elevator run; detecting whether the motor torque experienced by the electric motor during the constant speed portion of the elevator run was outside of the motor torque detection range that was adjusted based on the load within the elevator car and the center of gravity; and activating an alert if the motor torque experienced by the electric motor during the constant speed portion of the elevator run was outside of the motor torque detection range that was adjusted based on the load within the elevator car and the center of gravity.

[0023] Technical effects of embodiments of the present disclosure include testing brakes of a beam climber system by detecting increased motor torque on one of the electric motors driving the wheels.

[0024] The foregoing features and elements may be combined in various combinations without exclusivity, unless expressly indicated otherwise. These features and elements as well as the operation thereof will become more apparent in light of the following description and the accompanying drawings. It should be understood, however, that the following description and drawings are intended to be illustrative and explanatory in nature and non-limiting.

BRIEF DESCRIPTION OF THE DRAWINGS

[0025] The present disclosure is illustrated by way of example and not limited in the accompanying figures in which like reference numerals indicate similar elements.

FIG. 1 is a schematic illustration of an elevator system with a beam climber system, in accordance with an embodiment of the disclosure;

FIG. 2 illustrates a schematic view of a brake condition based monitoring system, in accordance with an embodiment of the disclosure;

FIG. 3 is a flow chart of method of detecting brake drag within an elevator system, in accordance with an embodiment of the disclosure; and

FIG. 4 is a flow chart of method of detecting brake drag within an elevator system, in accordance with an embodiment of the disclosure.

DETAILED DESCRIPTION

[0026] FIG. 1 is a perspective view of an elevator system 101 including an elevator car 103, a beam climber system 130, a controller 115, and a power source 120. Although illustrated in FIG. 1 as separate from the beam climber system 130, the embodiments described herein may be applicable to a controller 115 included in the beam climber system 130 (i.e., moving through an elevator shaft 117 with the beam climber system 130) and may also be applicable to a controller located off of the beam climber system 130 (i.e., remotely connected to the beam climber system 130 and stationary relative to the beam climber system 130). Although illustrated in FIG. 1 as separate from the beam climber system 130, the embodiments described herein may be applicable to a power source 120 included in the beam climber system 130 (i.e., moving through the elevator shaft 117 with the beam climber system 130) and may also be applicable to a power source located off of the beam climber system 130 (i.e., remotely connected to the beam climber system 130 and stationary relative to the beam climber system 130).

[0027] The beam climber system 130 is configured to move the elevator car 103 within the elevator shaft 117 and along guide rails 109a, 109b that extend vertically through the elevator shaft 117. In an embodiment, the guide rails 109a, 109b are T-beams. The beam climber system 130 includes one or more electric motors 132a, 132c. The electric motors 132a, 132c are configured to move the beam climber system 130 within the elevator shaft 117 by rotating one or more wheels 134a, 134c that are pressed against a guide beam 111a, 111b. In an embodiment, the guide beams 111a, 111b are I-beams. It is understood that while an I-beam is illustrated, any beam or similar structure may be utilized with the embodiment described herein. Friction between the wheels 134a, 134b, 134c, 134d driven by the electric motors 132a, 132c allows the wheels 134a, 134b, 134c, 134d to climb up 21 and down 22 the guide beams 111a, 111b. The guide beam extends vertically through the elevator shaft 117. It is understood that while two guide beams 111a, 111b are illustrated, the embodiments disclosed herein may be utilized with one or more guide beams. It is also understood that while two electric motors 132a, 132c are illustrated, the embodiments disclosed herein may be applicable to beam climber systems 130 having one or more electric motors. For example, the beam climber system 130 may have one electric motor for each of the four wheels 134a, 134b, 134c, 134d. The electrical motors 132a, 132c may be permanent magnet electrical motors, asynchronous motor, or any electrical motor known to one of skill in the art. In other embodiments, not illustrated herein, another configuration could have the powered wheels at two different vertical locations (i.e., at bottom and top of an elevator car 103).

[0028] The first guide beam 111a includes a web portion 113a and two flange portions 114a. The web portion 113a of the first guide beam 111a includes a first surface 112a and a second surface 112b opposite the first surface 112a. A first wheel 134a is in contact with the first surface 112a and a second wheel 134b is in contact with the second surface 112b. The first wheel 134a may be in contact with the first surface 112a through a tire 135 and the second wheel 134b may be in contact with the second surface 112b through a tire 135. The first wheel 134a is compressed against the first surface 112a of the first guide beam 111a by a first compression mechanism 150a and the second wheel 134b is compressed against the second surface 112b of the first guide beam 111a by the first compression mechanism 150a. The first compression mechanism 150a compresses the first wheel 134a and the second wheel 134b together to clamp onto the web portion 113a of the first guide beam 111a. The first compression mechanism 150a may be a metallic or elastomeric spring mechanism, a pneumatic mechanism, a hydraulic mechanism, a turnbuckle mechanism, an electromechanical actuator mechanism, a spring system, a hydraulic cylinder, a motorized spring setup, or any other known force actuation method. The first compression mechanism 150a may be adjustable in real-time during operation of the elevator system 101 to control compression of the first wheel 134a and the second wheel 134b on the first guide beam 111a. The first wheel 134a and the second wheel 134b may each include a tire 135 to increase traction with the first guide beam 111a.

[0029] The first surface 112a and the second surface 112b extend vertically through the shaft 117, thus creating a track for the first wheel 134a and the second wheel

134b to ride on. The flange portions 114a may work as guardrails to help guide the wheels 134a, 134b along this track and thus help prevent the wheels 134a, 134b from running off track.

[0030] The first electric motor 132a is configured to rotate the first wheel 134a to climb up 21 or down 22 the first guide beam 111a. The first electric motor 132a may also include a first motor brake 137a to slow and stop rotation of the first electric motor 132a. The first motor brake 137a may be mechanically connected to the first electric motor 132a. The first motor brake 137a may be a clutch system, a disc brake system, a drum brake system, a brake on a rotor of the first electric motor 132a, an electronic braking, an Eddy current brakes, a Magnetorheological fluid brake or any other known braking system. The beam climber system 130 may also include a first guide rail brake 138a operably connected to the first guide rail 109a. The first guide rail brake 138a is configured to slow movement of the beam climber system 130 by clamping onto the first guide rail 109a. The first guide rail brake 138a may be a caliper brake acting on the first guide rail 109a on the beam climber system 130, or caliper brakes acting on the first guide rail 109 proximate the elevator car 103.

[0031] The second guide beam 111b includes a web portion 113b and two flange portions 114b. The web portion 113b of the second guide beam 111b includes a first surface 112c and a second surface 112d opposite the first surface 112c. A third wheel 134c is in contact with the first surface 112c and a fourth wheel 134d is in contact with the second surface 112d. The third wheel 134c may be in contact with the first surface 112c through a tire 135 and the fourth wheel 134d may be in contact with the second surface 112d through a tire 135. A third wheel 134c is compressed against the first surface 112c of the second guide beam 111b by a second compression mechanism 150b and a fourth wheel 134d is compressed against the second surface 112d of the second guide beam 111b by the second compression mechanism 150b. The second compression mechanism 150b compresses the third wheel 134c and the fourth wheel 134d together to clamp onto the web portion 113b of the second guide beam 111b. The second compression mechanism 150b may be a spring mechanism, turnbuckle mechanism, an actuator mechanism, a spring system, a hydraulic cylinder, and/or a motorized spring setup. The second compression mechanism 150b may be adjustable in real-time during operation of the elevator system 101 to control compression of the third wheel 134c and the fourth wheel 134d on the second guide beam 111b. The third wheel 134c and the fourth wheel 134d may each include a tire 135 to increase traction with the second guide beam 111b.

[0032] The first surface 112c and the second surface 112d extend vertically through the shaft 117, thus creating a track for the third wheel 134c and the fourth wheel 134d to ride on. The flange portions 114b may work as guardrails to help guide the wheels 134c, 134d along this track and thus help prevent the wheels 134c, 134d from running off track.

[0033] The third electric motor 132c is configured to rotate the third wheel 134c to climb up 21 or down 22 the second guide beam 111b. The third electric motor 132c may also include a third motor brake 137c to slow and stop rotation of the third electric motor 132c. The third motor brake 137c may be mechanically connected to the third electric motor 132c. The third motor brake 137c may be a clutch system, a disc brake system, drum brake system, a brake on a rotor of the second electric motor 132b, an electronic braking, an Eddy current brake, a Magnetorheological fluid brake, or any other known braking system. The beam climber system 130 includes a second guide rail brake 138b operably connected to the second guide rail 109b. The second guide rail brake 138b is configured to slow movement of the beam climber system 130 by clamping onto the second guide rail 109b. The second guide rail brake 138b may be a caliper brake acting on the first guide rail 109a on the beam climber system 130, or caliper brakes acting on the first guide rail 109 proximate the elevator car 103.

[0034] The elevator system 101 may also include a position reference system 113. The position reference system 113 may be mounted on a fixed part at the top of the elevator shaft 117, such as on a support or guide rail 109, and may be configured to provide position signals related to a position of the elevator car 103 within the elevator shaft 117. In other embodiments, the position reference system 113 may be directly mounted to a moving component of the elevator system (e.g., the elevator car 103 or the beam climber system 130), or may be located in other positions and/or configurations as known in the art. The position reference system 113 can be any device or mechanism for monitoring a position of an elevator car within the elevator shaft 117, as known in the art. For example, without limitation, the position reference system 113 can be an encoder, sensor, accelerometer, altimeter, pressure sensor, range finder, or other system and can include velocity sensing, absolute position sensing, etc., as will be appreciated by those of skill in the art.

[0035] The controller 115 may be an electronic controller including a processor 116 and an associated memory 119 comprising computer-executable instructions that, when executed by the processor 116, cause the processor 116 to perform various operations. The processor 116 may be, but is not limited to, a single-processor or multiprocessor system of any of a wide array of possible architectures, including field programmable gate array (FPGA), central processing unit (CPU), application specific integrated circuits (ASIC), digital signal processor (DSP) or graphics processing unit (GPU) hardware arranged homogenously or heterogeneously. The memory 119 may be but is not limited to a random access memory (RAM), read only memory (ROM), or other electronic, optical, magnetic or any other computer readable medium.

[0036] The controller 115 is configured to control the operation of the elevator car 103 and the beam climber system 130. For example, the controller 115 may provide drive signals to the beam climber system 130 to control the acceleration, deceleration, leveling, stopping, etc. of the elevator car 103.

[0037] The controller 115 may also be configured to receive position signals from the position reference system 113 or any other desired position reference device.

[0038] When moving up 21 or down 22 within the elevator shaft 117 along the guide rails 109a, 109b, the elevator car 103 may stop at one or more landings 125 as controlled by the controller 115. In one embodiment, the controller 115 may be located remotely or in the cloud. In another embodiment, the controller 115 may be located on the beam climber system 130.

[0039] The power supply 120 for the elevator system 101 may be any power source, including a power grid and/or battery power which, in combination with other components, is supplied to the beam climber system 130. In one embodiment, power source 120 may be located on the beam climber system 130. In an embodiment, the power supply 120 is a battery that is included in the beam climber system 130.

[0040] The elevator system 101 may also include an accelerometer 107 attached to the elevator car 103 or the beam climber system 130. The accelerometer 107 is configured to detect an acceleration and/or a speed of the elevator car 103 and the beam climber system 130.

[0041] Referring now to FIG. 2, with continued reference to FIG. 1, a brake condition based monitoring system 200 is illustrated, in accordance with an embodiment of the present disclosure. It should be appreciated that, although particular systems are separately defined in the schematic block diagrams, each or any of the systems may be otherwise combined or separated via hardware and/or software. In one embodiment, the brake condition based monitoring system 200 may be a separate hardware module in electronic communication with the controller 115. The separate hardware module may be local or remote (e.g., software as a service). In another embodiment, the brake condition based monitoring system 200 may be software installed directly on the memory 119 of the controller 115 and the software may consist of operations to be performed by the processor 116.

[0042] The elevator system 101 includes at least one brake 137a, 137b, 137c, 137d, 138a, 138b configured to slow the elevator car 103. The brake condition based monitoring system 200 is configured to assess the health and braking force or torque of brakes 137a, 137b, 137c, 137d, 138a, 138b of the beam climber system 130. Specifically, the brake condition based monitoring system 200 is configured to determine a brake health of the brakes 137a, 137b, 137c, 137d, 138a, 138b of the beam climber system 130. More specifically, the brake condition based monitoring system 200 is configured to determine whether the brake does not have adequate clearance with its associated braking surface (i.e., whether the brake sticking). The brakes 137a, 137b, 137c, 137d, 138a, 138b of the beam climber system 130 includes the first motor brake 137a, a second motor brake 137b, the third motor brake 137c, a fourth motor brake 137d, the first guide rail brake 138a, and the second guide rail brake 138b.

[0043] The beam climber system also includes a second electric motor 132b configured to move the beam climber system 130 by rotating the second wheel 134b and a fourth electric motor 132d configured to move the beam climber system 130 by rotating the fourth wheel 134d. The first wheel 134a and the second wheel 134b are pressed against the first guide beam 111a. The third wheel 134c and the fourth wheel 134d is pressed up against the second guide beam 111b.

[0044] Friction between the wheels 134a, 134b, 134c, 134d driven by the electric motors 132a, 132b, 132b, 132c allows the wheels 134a, 134b, 134c, 134d to climb up 21 and down 22 the guide beams 111a, 111b. The guide beam extends vertically through the elevator shaft 117. It is understood that while two guide beams 111a, 111b are illustrated, the embodiments disclosed herein may be utilized with one or more guide beams. The electrical motors 132a, 132b, 132c, 134d may be permanent magnet electrical motors, asynchronous motor, or any electrical motor known to one of skill in the art.

[0045] The second electric motor 132b is configured to rotate the second wheel 134b to climb up 21 or down 22 the first guide beam 111a. The second electric motor 132b may also include a second motor brake 137b to slow and stop rotation of the second electric motor 132b. The second motor brake 137b may be mechanically connected to the second electric motor 132b. The second motor brake 137b may be a clutch system, a disc brake system, a drum brake system, a brake on a rotor of the first electric motor 132a, an electronic braking, an Eddy current brakes, a Magnetorheological fluid brake or any other known braking system.

[0046] The fourth electric motor 132d is configured to rotate the fourth wheel 134d to climb up 21 or down 22 the second guide beam 111b. The fourth electric motor 132d may also include a fourth motor brake 137d to slow and stop rotation of the fourth electric motor 132d. The fourth motor brake 137d may be mechanically connected to the fourth electric motor 132d. The fourth motor brake 137d may be a clutch system, a disc brake system, a drum brake system, a brake on a rotor of the first electric motor 132a, an electronic braking, an Eddy current brakes, a Magnetorheological fluid brake or any other known braking system.

[0047] The brake condition based monitoring system 200 is configured to detect when a braking clearance of the first motor brake 137a is less than a prescribed braking clearance for the first motor brake 137a (i.e., when the first motor brake 137a is dragging), when a braking clearance of the second motor brake 137b is less than a prescribed braking clearance for the second motor brake 137b(i.e., when the second motor brake 137b is dragging), when a braking clearance of the third motor brake

137c is less than a prescribed braking clearance for the third motor brake 137c (i.e., when the third motor brake 137d is dragging), when a braking clearance of the fourth motor brake 137d is less than a prescribed braking clearance for the fourth motor brake 137d (i.e., when the fourth motor brake 137d is dragging), when a braking clearance of the first guide rail brake 138a is less than a prescribed braking clearance for the first guide rail brake 138a (i.e., when the first guide rail brake 138a is dragging), and/or a braking clearance of the second guide rail brake 138b is less than a prescribed braking clearance for the second guide rail brake 138b (i.e., when the second guide rail brake 138a is dragging) based upon at least a torque of the first electric motor 132a, the second electric motor 132b, third electric motor 132c, and/or the fourth electric motor 132d. The torque on each electric motor 132a, 132b, 132b, 132c may be measured based upon the electric voltage being sent to each electric motor 132a, 132b, 132b, 132c. Torque may also be monitored using a sensor, such as strain gauge. From a detection of abnormal torque, it may be inferred that there is a lack of adequate clearance for a brake 137a, 137b, 137c, 137d, 138a, 138b or in other words the brake 137a, 137b, 137c, 137d, 138a, 138b is dragging.

[0048] In an example, a torque v. motor speed chart 220 illustrates a torque 222 of the first electric motor 132a, a torque 224 of the second electric motor 132b, a torque 226 of the third electric motor 132c, and/or a torque 228 the fourth electric motor 132d. If commanded by the controller 115 to rotate at the same speed the first electric motor 132a, second electric motor 132b, the third electric motor 132c, and the fourth electric motor 132d should each see relatively the same torque. When the torque of one electric motor is higher than the torque on the other electric motors, it may indicate that the motor with the higher torque may be experiencing increase drag, which may be caused by a dragging brake or in other words a brake with a braking clearance that is less than a prescribed braking clearance. For example, the torque v. motor speed chart 220 illustrates the torque 228 on the fourth electric motor 132d being higher than the torque 222 of the first electric motor 132a, the torque 224 of the second electric motor 132b, and the torque 226 of the third electric motor 132c, thus this may be indicative that the fourth motor brake 137d is dragging or sticking. Conversely, when moving downwards, a motor 137a, 137b, 137c, 137d with less torque may indicate a dragging brake 137a, 137b, 137c, 137d, 138a, 138b.

[0049] The brake conditioning system 200 may be configured to take into account other parameters that may cause an increase in torque on the electric motors 132a, 132b, 132b, 132c, such as, for example passenger loads within the elevator car. For example, the if all the passengers in the elevator car 103 are located in the portion of the elevator car 103 proximate the first electric motor 132a, that may cause increased torque on the first electric motor 132a. This may be expected in pairs of motors 132a, 132b, 132b, 132c with wheels 134a, 134b, 134c, 134d pinching the same guide beam 111a, 111b.

[0050] The elevator car 103 may include a floor pressure sensor, which may be one or more pressure sensors located in the floor of an elevator car 103 that utilizes pressure data on the floor to detect a human and/or an object within the elevator car 103 to help determine a center of gravity 103a of the elevator car 103 and a load with the elevator car 103. The floor pressure sensor generates a pressure map for analysis. Another load weighing system that can be used to isolate the center of the elevator car 103 load is to put load cells under the car platform at various locations. For example, the load weighing system may include four load cells spaced in a rectangular arrangement (e.g., front/left, front/right, back/left, back/right) and from the readings of these load cells the total force in the car and its X/Y location can be resolved. It is understood that any other desired load measurement system may be utilized. Further the loads within the elevator car 103 may be measure when the elevator car is stationary to obtain a baseline load measurement.

[0051] As shown in the center of gravity chart 300, the brake conditioning system 200 may determine the center of gravity 103a of the elevator car 103. If the center of gravity 103a shifts closer towards any wheel 134a, 134b, 134c, 134d, (as measured on a floor 103b of the elevator car 103) then that may increase torque on the electric motor 132a, 132b, 132c, 132d of the wheel 134a, 134b, 134c, 134d. The brake conditioning system 200 may break down the elevator car 103 into four quadrants 310a, 310b, 310c, 310d including a first quadrant 310a, a second quadrant 310b, a third quadrant 310c, and a fourth quadrant 310d and calculate the loads in each of the first quadrant 310a, the second quadrant 310b, the third quadrant 310c, and the fourth quadrant 310d in order to determine the center of gravity 103a of the elevator car 103.

[0052] The brake condition monitoring system 200 may be configured to normalize the effect of that the center of gravity 103a of the elevator car 103 may have on the torque 222 of the first electric motor 132a, the torque 224 of the second electric motor 132b, the torque 226 of the third electric motor 132c, and the torque 228 the fourth electric motor 132d. By normalizing the effect of the center of gravity 103a, the brake condition monitoring system 200 may then attribute excess torque on any particular electric motor 132a, 132b, 132b, 132c to the braking clearance being less than the prescribed braking clearance of the respective motor brake 137a, 137b, 137c, 137d, or in other words the motor brake 137a, 137b, 137c, 137d is sticking or dragging.

[0053] If two motors 132a, 132b, 132c, 132d on the same guide beam 109a, 109b are experiencing a similar increase in torque then it may indicate that the proximate guide rail brake 138a, 138b has a braking clearance being less than the prescribed braking clearance of the respective guide rail brake 138a, 138b. In one example, if the first electric motor 132a and the second electric motor

132b are experiencing similar increases in torque than either the first guide rail brake 138a may be sticking and/or the first motor brake 137a and the third motor break 137b may be sticking. In another example, if the third electric motor 132c and the fourth electric motor 132c are experiencing similar increases in torque than either the second guide rail brake 138b may be sticking and/or the third motor brake 137c and the fourth motor brake 137d may be sticking.

[0054] Referring now to FIG. 3, with continued reference to FIGS. 1-2, a flow chart of method 400 of detecting brake drag within an elevator systems 101 is illustrated, in accordance with an embodiment of the disclosure.

[0055] At block 404, a first electric motor 132a of a beam climber system 130 rotates a first wheel 134a. The first wheel 134a being in contact with a first surface 112a of a first guide beam 111a that extends vertically through an elevator shaft 117.

[0056] At block 406, the beam climber system 130 moves an elevator car 103 through the elevator shaft when the first wheel 134a of the beam climber system 130 rotates along the first surface 112a of the first guide beam 111a.

[0057] At block 408, a brake condition based monitoring system 200 detects when the first motor brake 137a is dragging (i.e., when a braking clearance of the first motor brake 137a is less than a prescribed braking clearance of the first motor brake 137a) based upon at least a torque of the first electric motor 132a.

[0058] The method 400 may further comprise a center of gravity 103a of the elevator car 103. The brake condition based monitoring system 200 is configured to detect when the first motor brake 137a is dragging (i.e., when a braking clearance of the first motor brake 137a is less than a prescribed braking clearance of the first motor brake 137a) based upon at least a torque of the first electric motor 132a and the center of gravity 103a.

[0059] The method 400 may further comprise that the torque of the first electric motor 132a is normalized based on the center of gravity 103a of the elevator car 103.

[0060] The method 400 may further comprise that a second electric motor 132b of a beam climber system rotates a second wheel 134b. The second wheel 134b being in contact with a second surface of a first guide beam 111a. The beam climber system moves the elevator car 103 through the elevator shaft 117 when the first wheel 134a of the beam climber system rotates along the first surface of the first guide beam 111a and the second wheel 134b of the beam climber system rotates along the second surface of the first guide beam 111a. The brake condition based monitoring system 200 detects at least one of when the first motor brake 137a is dragging (i.e., when a braking clearance of a first motor brake 137a is less than a prescribed braking clearance of the first motor brake 137a) or when the third motor brake 137c is dragging (i.e., when a braking clearance of a third motor brake 137c is less than a prescribed braking clearance of the third motor brake 137c).

[0061] The method 400 may further comprise that the brake condition monitoring system detects when the first guide rail brake 138a is dragging (i.e., when the braking clearance of the first guide rail 109a brake is less than a prescribed braking clearance of the first guide rail brake 138a) based upon at least a torque of the first electric motor 132a and the torque of the second electric motor 132b.

[0062] The method 400 may further include that a second electric motor 132b of a beam climber system rotates a second wheel 134b, a third electric motor 132c of a beam climber system rotates a third wheel 134c, and a fourth electric motor 132d rotates a fourth wheel 134d. The second wheel 134b being in contact with a second surface of the first guide beam 111a, the third wheel 134c being in contact with a first surface of a second guide beam 111b that extends vertically through the elevator shaft 117, and the fourth wheel 134d being in contact with a second surface of the second guide beam 111b. The beam climber system move the elevator car 103 through the elevator shaft 117 when the first wheel 134a of the beam climber system rotates along the first surface of the first guide beam 111a, the second wheel 134b of the beam climber system rotates along the second surface of the first guide beam 111a, the third wheel 134c rotates along the first surface of the second guide beam 111b, and the fourth wheel 134d rotates along the second surface of the second guide beam 111b. The brake condition based monitoring system 200 detects at least one of when the first motor brake 137a is dragging (i.e., when a braking clearance of a first motor brake 137a is less than a prescribed braking clearance of the first motor brake 137a), when the second motor brake 137b is dragging (i.e., when a braking clearance of a second motor brake 137b is less than a prescribed braking clearance of the second motor brake 137b), when the third motor brake 137c is dragging (i.e., when a braking clearance of a third motor brake 137c is less than a prescribed braking clearance of the third motor brake 137c), or when the fourth motor brake 137d is dragging (i.e., when a braking clearance of a fourth motor brake 137d is less than a prescribed braking clearance of the fourth motor brake 137d).While the above description has described the flow process of FIG. 3 in a particular order, it should be appreciated that unless otherwise specifically required in the attached claims that the ordering of the steps may be varied.

[0063] Referring now to FIG. 4, with continued reference to FIGS. 1-2, a flow chart of method 500 of detecting brake drag within an elevator systems 101 is illustrated, in accordance with an embodiment of the disclosure. It is understood that while method 400 discusses the electric motor in the singular, any number of electric motors can be utilized. At block 504, a load within the elevator car 103 is detected. At block 506, the center of gravity 103a of the elevator car 103 is also determined. At block 508, a predicted motor torque of the electric motor 132a, 132b, 132c, 132d during a constant speed of the elevator car 103 is determined. At block 510, a motor torque detection range for the electric motor 132a, 132b, 132c, 132d is adjusted based on the load within the elevator car 103 and the center of gravity 103a, or in other words the torque is normalized. At block 512, the beam climber system 130 moves the elevator car 103 for an elevator run and the motor torques experienced by the electric motor 132a, 132b, 132c, 132d is recorded during a constant speed portion of the elevator run. At block 514, It is detected whether the motor torque experienced by the electric motor 132a, 132b, 132c, 132d during the constant speed portion of the elevator run was outside of the motor torque detection range that was adjusted based on the load within the elevator car 103 and the center of gravity 103a. At block 516, an alert may be activated if the motor torque experienced by the electric motor 132a, 132b, 132c, 132d during the constant speed portion of the elevator run was outside of the motor torque detection range that was adjusted based on the load within the elevator car 103 and the center of gravity 103a

[0064] While the above description has described the flow process of FIG. 4 in a particular order, it should be appreciated that unless otherwise specifically required in the attached claims that the ordering of the steps may be varied.

[0065] The present invention may be a system, a method, and/or a computer program product at any possible technical detail level of integration. The computer program product may include a computer readable storage medium (or media) having computer readable program instructions thereon for causing a processor to carry out aspects of the present invention.

[0066] As described above, embodiments can be in the form of processor-implemented processes and devices for practicing those processes, such as processor. Embodiments can also be in the form of computer program code (e.g., computer program product) containing instructions embodied in tangible media (e.g., non-transitory computer readable medium), such as floppy diskettes, CD ROMs, hard drives, or any other non-transitory computer readable medium, wherein, when the computer program code is loaded into and executed by a computer, the computer becomes a device for practicing the embodiments. Embodiments can also be in the form of computer program code, for example, whether stored in a storage medium, loaded into and/or executed by a computer, or transmitted over some transmission medium, loaded into and/or executed by a computer, or transmitted over some transmission medium, such as over electrical wiring or cabling, through fiber optics, or via electromagnetic radiation, wherein, when the computer program code is loaded into and executed by a computer, the computer becomes an device for practicing the exemplary embodiments. When implemented on a general-purpose microprocessor, the computer program code segments configure the microprocessor to create specific logic circuits.

[0067] The term "about" is intended to include the degree of error associated with measurement of the particular quantity and/or manufacturing tolerances based upon the equipment available at the time of filing the application.

[0068] The terminology used herein is for the purpose of describing particular embodiments only and is not intended to be limiting of the present disclosure. As used herein, the singular forms "a", "an" and "the" are intended to include the plural forms as well, unless the context clearly indicates otherwise. It will be further understood that the terms "comprises" and/or "comprising," when used in this specification, specify the presence of stated features, integers, steps, operations, elements, and/or components, but do not preclude the presence or addition of one or more other features, integers, steps, operations, element components, and/or groups thereof.

[0069] Those of skill in the art will appreciate that various example embodiments are shown and described herein, each having certain features in the particular embodiments, but the present disclosure is not thus limited. Rather, the present disclosure can be modified to incorporate any number of variations, alterations, substitutions, combinations, sub-combinations, or equivalent arrangements not heretofore described, but which are commensurate with the scope of the present disclosure. Additionally, while various embodiments of the present disclosure have been described, it is to be understood that aspects of the present disclosure may include only some of the described embodiments. Accordingly, the present disclosure is not to be seen as limited by the foregoing description, but is only limited by the scope of the appended claims.

Claims

1. An elevator system comprising:

an elevator car configured to travel through an elevator shaft;

a first guide beam extending vertically through the elevator shaft, the first guide beam comprising a first surface and a second surface opposite the first surface;

a beam climber system configured to move the elevator car through the elevator shaft, the beam climber system comprising:

a first wheel in contact with the first surface; and

a first electric motor configured to rotate the first wheel;

a first motor brake mechanically connected to the first electric motor, the first motor brake configured to slow the elevator car; and

a brake condition based monitoring system configured to detect when the first motor brake is dragging.

2. The elevator system of claim 1, wherein the brake condition based monitoring system is configured to detect when the first motor brake is dragging based upon at least a torque of the first electric motor.

3. The elevator system of claim 2, further comprising: a floor pressure sensor configured to determine a center of gravity of the elevator car, wherein the brake condition based monitoring system is configured to detect when the first motor brake is dragging based upon at least the torque of the first electric motor and the center of gravity.

4. The elevator system of claim 3, wherein the brake condition monitoring system is configured to normalize the torque of the first electric motor based on the center of gravity of the elevator car.

5. The elevator system of any preceding claim, wherein the beam climber system further comprises:

   a second wheel in contact with the second surface;
   a second electric motor configured to rotate the second wheel; and
   a second motor brake mechanically connected to the second electric motor, the second motor brake configured to slow the elevator car,
   wherein the brake condition based monitoring system is configured to detect when the second motor brake is dragging.

6. The elevator system of claim 5, wherein the brake condition based monitoring system is configured to detect when the second motor brake is dragging based upon at least a torque of the second electric motor.

7. The elevator system of claim 5 or 6, further comprising:

   a first guide rail extending vertically through the elevator shaft,
   wherein the beam climber system further comprises:

      a first guide rail brake operably connected to the first guide rail,
      wherein the brake condition monitoring system is configured to detect when the first guide rail brake is dragging based upon at least a torque of the first electric motor and the torque of the second electric motor.

8. The elevator system of any preceding claim, further comprising:

   a second guide beam extending vertically through the elevator shaft, the second guide beam comprising a first surface of the second guide beam and a second surface of the second guide beam opposite the first surface of the second guide beam,
   wherein the beam climber system further comprises:

      a second wheel in contact with the second surface of the first guide beam;
      a second electric motor configured to rotate the second wheel;
      a second motor brake mechanically connected to the second electric motor, the second motor brake configured to slow the elevator car;
      a third wheel in contact with the first surface of the second guide beam;
      a third electric motor configured to rotate the third wheel;
      a third motor brake mechanically connected to the third electric motor, the third motor brake configured to slow the elevator car;
      a fourth wheel in contact with the second surface of the second guide beam;
      a fourth electric motor configured to rotate the fourth wheel;
      a fourth motor brake mechanically connected to the fourth electric motor, the fourth motor brake configured to slow the elevator car,
      wherein the brake condition based monitoring system is configured to detect when second motor brake is dragging, detect when the third motor brake is dragging, and detect when the fourth motor brake is dragging.

9. The elevator system of claim 8, further comprising:

   a second guide rail extending vertically through the elevator shaft,
   wherein the beam climber system further comprises:

      a second guide rail brake operably connected to the second guide rail,
      wherein the brake condition monitoring system is configured to detect when the second guide rail brake is dragging based upon at least a torque of the third electric motor and a torque of the fourth electric motor.

10. The elevator system of claim 8 or 9, further comprising:
a floor pressure sensor configured to determine a center of gravity of the elevator car, wherein the brake condition based monitoring system is configured to detect at least one of when the first motor

brake is dragging, detect when the second motor brake is dragging, detect when the third motor brake is dragging, or detect when the fourth motor brake is dragging based upon at least the torque of the first electric motor, a torque of the second electric motor, a torque of the third electric motor, a torque of the fourth electric motor, and the center of gravity.

11. The elevator system of any of claims 8-10, wherein the brake condition monitoring system is configured to normalize the torque of the first electric motor, the second electric motor, the third electric motor, and the fourth electric motor based on the center of gravity of the elevator car.

12. A method of detecting brake drag within an elevator system, the method comprising:

rotating, using a first electric motor of a beam climber system, a first wheel, the first wheel being in contact with a first surface of a first guide beam that extends vertically through an elevator shaft;
moving, using the beam climber system, an elevator car through the elevator shaft when the first wheel of the beam climber system rotates along the first surface of the first guide beam; and
detecting, using a brake condition based monitoring system, when a first motor brake is dragging.

13. The method of claim 12, further comprising:

detecting a torque of the first electric motor, wherein the brake condition based monitoring system is configured to detect when the first motor brake is dragging based upon at least a torque of the first electric motor; and optionally
detecting a center of gravity of the elevator car, wherein the brake condition based monitoring system is configured to detect when the first motor brake is dragging based upon at least a torque of the first electric motor and the center of gravity; and optionally
normalizing the torque of the first electric motor based on the center of gravity of the elevator car.

14. The method claim 12 or 13, further comprising:

rotating, using a second electric motor of the beam climber system, a second wheel, the second wheel being in contact with a second surface of the first guide beam;
moving, using the beam climber system, the elevator car through the elevator shaft when the first wheel of the beam climber system rotates along the first surface of the first guide beam and the second wheel of the beam climber system rotates along the second surface of the first guide beam; and
detecting, using the brake condition based monitoring system, at least one of when the first motor brake is dragging or when the second motor brake is dragging; and optionally
wherein the elevator system further comprises a first guide rail extending vertically through the elevator shaft,
wherein the beam climber system further comprises a first guide rail brake operably connected to the first guide rail,
wherein the method further comprises:
detecting, using the brake condition monitoring system, when the first guide rail brake is dragging based upon at least a torque of the first electric motor and a torque of the second electric motor.

15. A method of detecting brake drag within an elevator system, the method comprising:

detecting a load within an elevator car;
determining a center of gravity of the elevator car;
determining a predicted motor torque of an electric motor of a beam climber assembly during a constant speed of the elevator car;
adjusting a motor torque detection range for the electric motor based on the load within the elevator car and the center of gravity;
moving the elevator car, using the beam climber system, for an elevator run and recording the motor torque experienced by the electric motor during a constant speed portion of the elevator run;
detecting whether the motor torque experienced by the electric motor during the constant speed portion of the elevator run was outside of the motor torque detection range that was adjusted based on the load within the elevator car and the center of gravity; and
activating an alert if the motor torque experienced by the electric motor during the constant speed portion of the elevator run was outside of the motor torque detection range that was adjusted based on the load within the elevator car and the center of gravity.

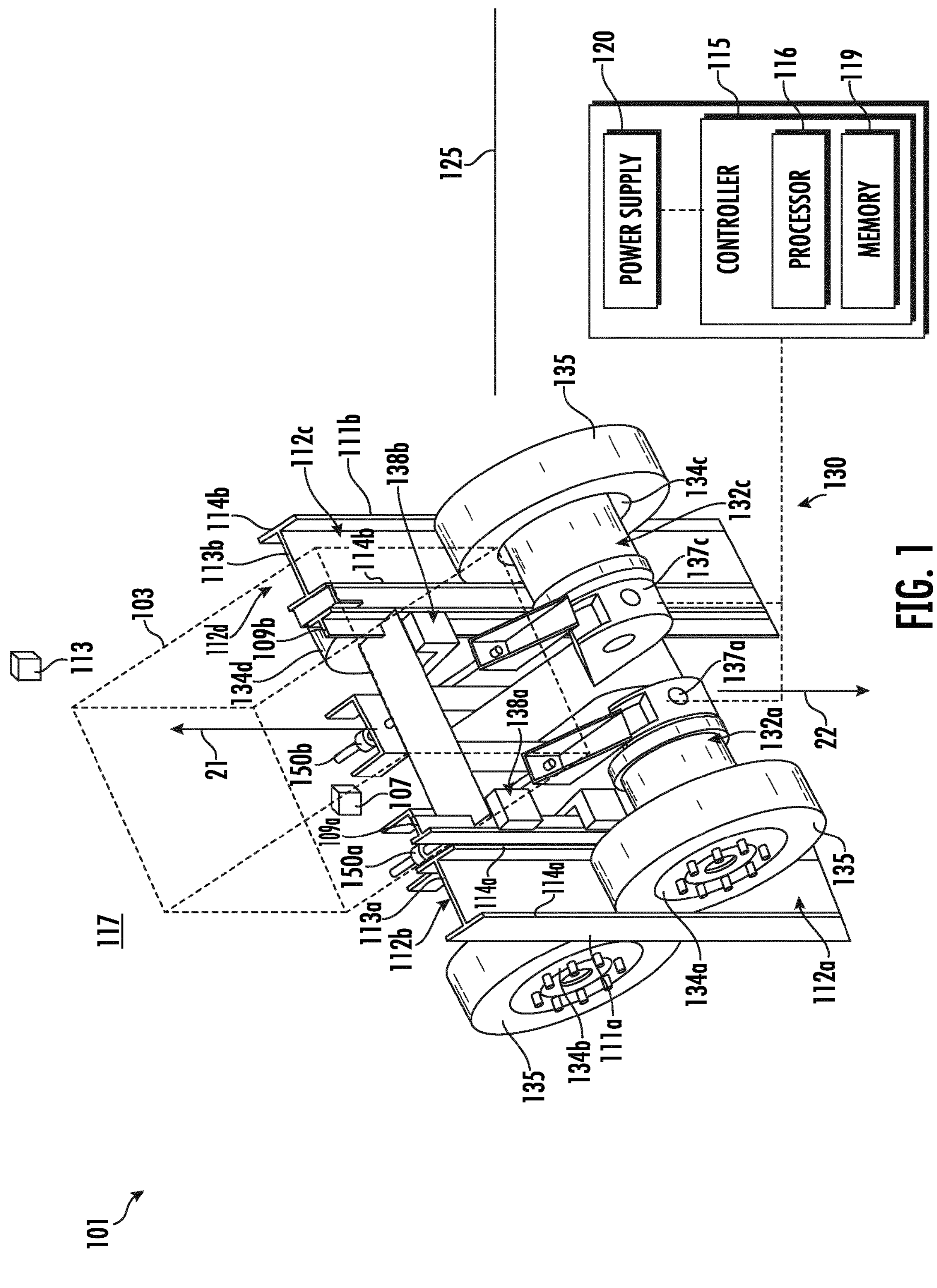
POWER SUPPLY
CONTROLLER
PROCESSOR
MEMORY
120
115
116
119
125
130
135
101
117
103
113
107
21
22
109a
109b
111a
111b
112a
112b
112c
112d
113a
113b
114a
114b
132a
132c
134a
134b
134c
134d
137a
137c
138a
138b
150a
150b

FIG. 1

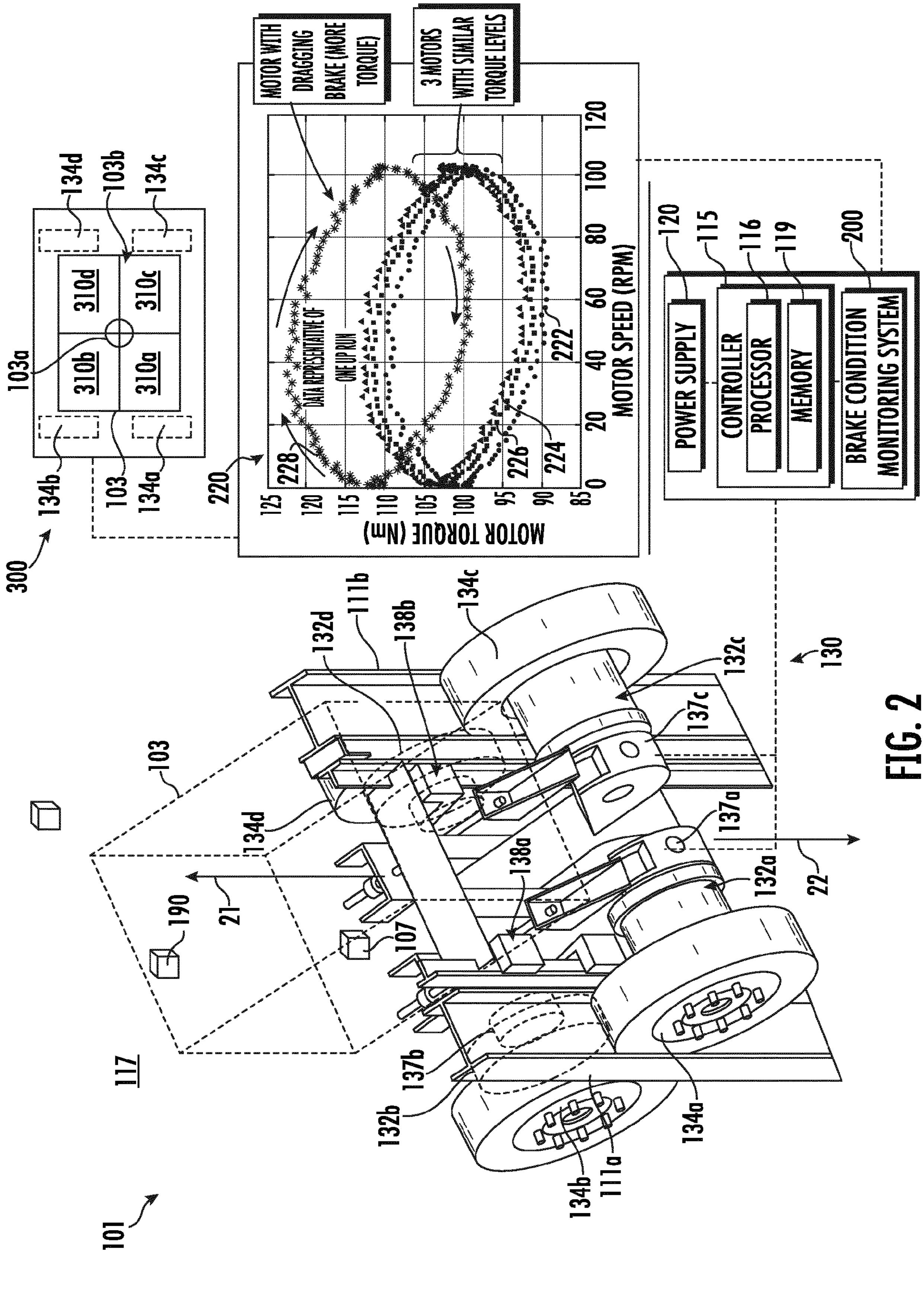
MOTOR WITH DRAGGING BRAKE (MORE TORQUE)
3 MOTORS WITH SIMILAR TORQUE LEVELS
DATA REPRESENTATIVE OF ONE UP RUN
MOTOR TORQUE (Nm)
MOTOR SPEED (RPM)
POWER SUPPLY
CONTROLLER
PROCESSOR
MEMORY
BRAKE CONDITION MONITORING SYSTEM
310a
310b
310c
310d
300
220
101
117

FIG. 2

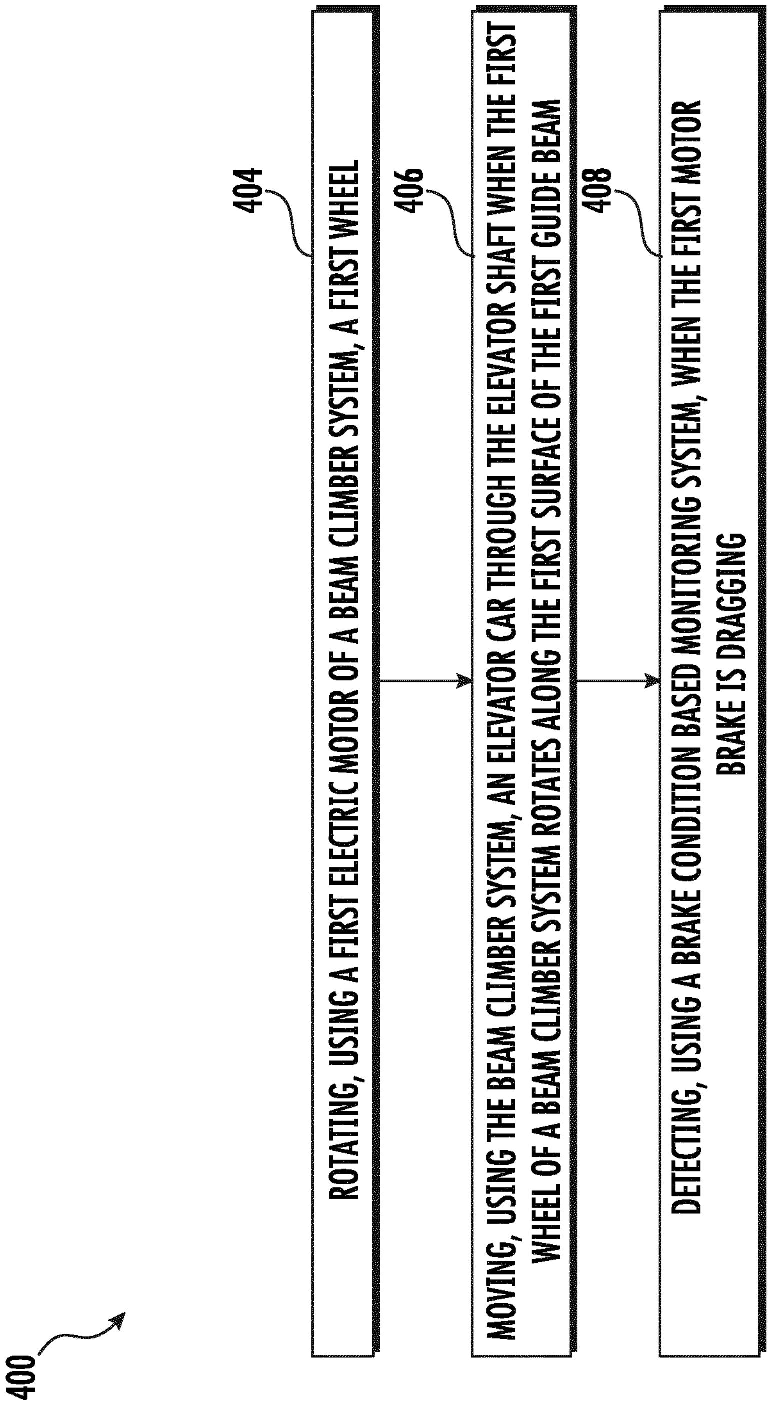
400
404
ROTATING, USING A FIRST ELECTRIC MOTOR OF A BEAM CLIMBER SYSTEM, A FIRST WHEEL
406
MOVING, USING THE BEAM CLIMBER SYSTEM, AN ELEVATOR CAR THROUGH THE ELEVATOR SHAFT WHEN THE FIRST WHEEL OF A BEAM CLIMBER SYSTEM ROTATES ALONG THE FIRST SURFACE OF THE FIRST GUIDE BEAM
408
DETECTING, USING A BRAKE CONDITION BASED MONITORING SYSTEM, WHEN THE FIRST MOTOR BRAKE IS DRAGGING

FIG. 3

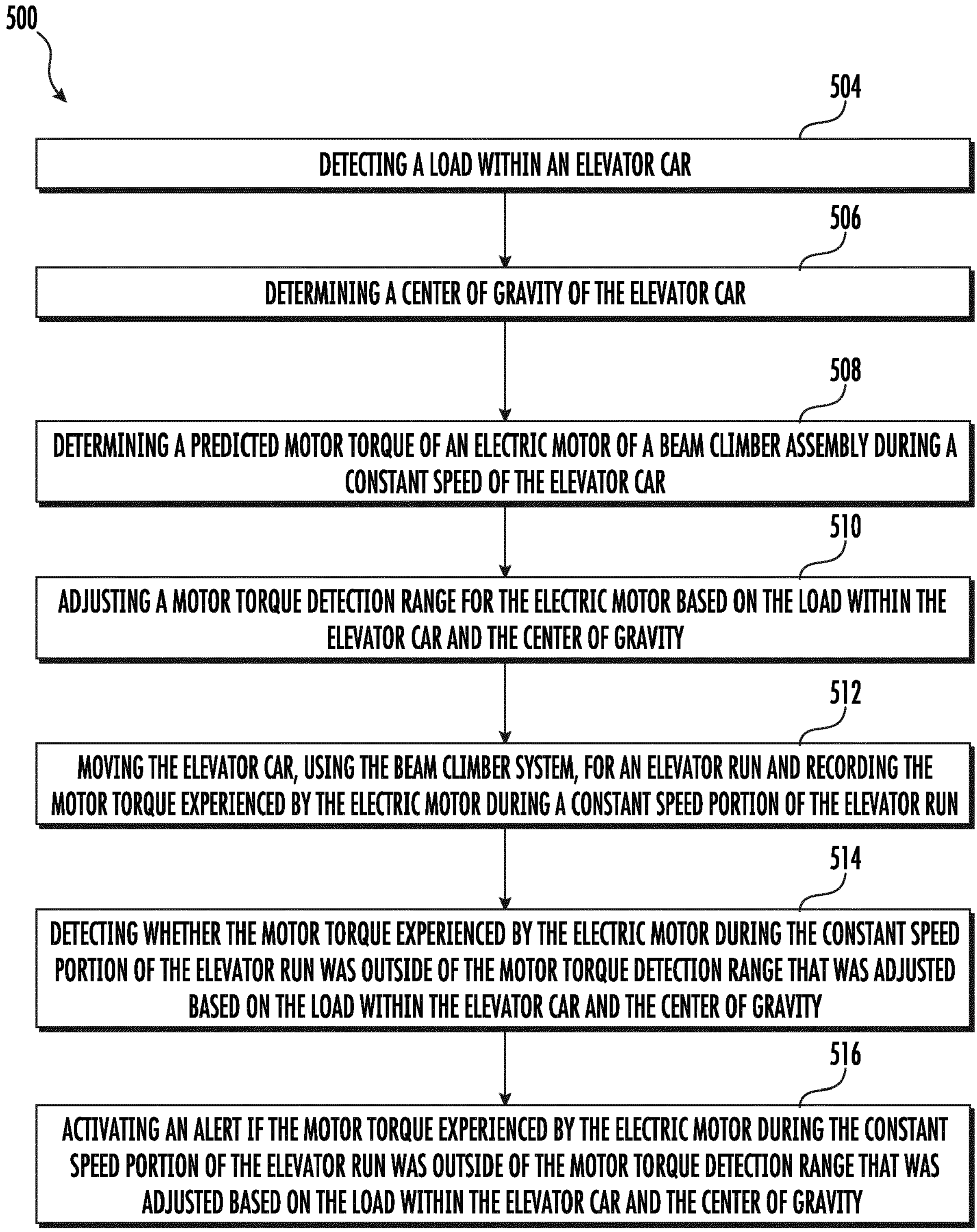
500
504
DETECTING A LOAD WITHIN AN ELEVATOR CAR
506
DETERMINING A CENTER OF GRAVITY OF THE ELEVATOR CAR
508
DETERMINING A PREDICTED MOTOR TORQUE OF AN ELECTRIC MOTOR OF A BEAM CLIMBER ASSEMBLY DURING A CONSTANT SPEED OF THE ELEVATOR CAR
510
ADJUSTING A MOTOR TORQUE DETECTION RANGE FOR THE ELECTRIC MOTOR BASED ON THE LOAD WITHIN THE ELEVATOR CAR AND THE CENTER OF GRAVITY
512
MOVING THE ELEVATOR CAR, USING THE BEAM CLIMBER SYSTEM, FOR AN ELEVATOR RUN AND RECORDING THE MOTOR TORQUE EXPERIENCED BY THE ELECTRIC MOTOR DURING A CONSTANT SPEED PORTION OF THE ELEVATOR RUN
514
DETECTING WHETHER THE MOTOR TORQUE EXPERIENCED BY THE ELECTRIC MOTOR DURING THE CONSTANT SPEED PORTION OF THE ELEVATOR RUN WAS OUTSIDE OF THE MOTOR TORQUE DETECTION RANGE THAT WAS ADJUSTED BASED ON THE LOAD WITHIN THE ELEVATOR CAR AND THE CENTER OF GRAVITY
516
ACTIVATING AN ALERT IF THE MOTOR TORQUE EXPERIENCED BY THE ELECTRIC MOTOR DURING THE CONSTANT SPEED PORTION OF THE ELEVATOR RUN WAS OUTSIDE OF THE MOTOR TORQUE DETECTION RANGE THAT WAS ADJUSTED BASED ON THE LOAD WITHIN THE ELEVATOR CAR AND THE CENTER OF GRAVITY

FIG. 4

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European Patent Office
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EUROPEAN SEARCH REPORT

Application Number
EP 21 18 8963

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Place of search	Date of completion of the search	Examiner
The Hague	3 December 2021	Dijoux, Adrien

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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D : document cited in the application
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EPO FORM 1503 03.82 (P04C01)

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EP 21 18 8963

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The members are as contained in the European Patent Office EDP file on
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For more details about this annex : see Official Journal of the European Patent Office, No. 12/82