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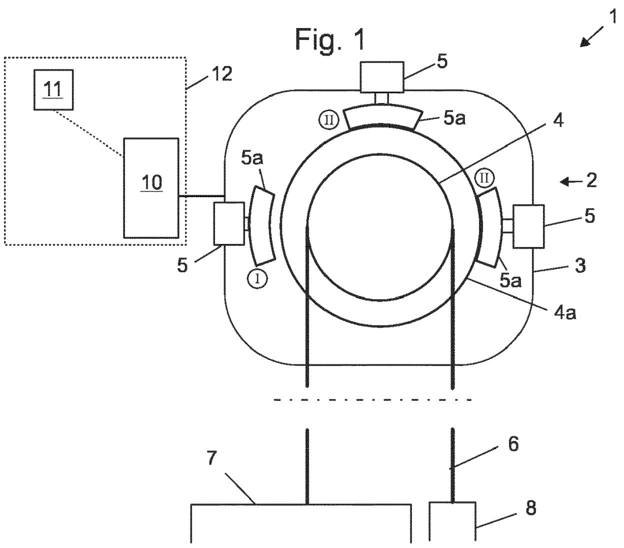
(54) METHOD FOR MONITORING ELEVATOR BRAKES AND ELEVATOR ARRANGEMENT

(57) The invention relates to a method for monitoring brakes of a multi-brake hoisting machinery (2), the method comprising performing a test sequence (100), wherein the test sequence comprises: holding (101) at least one brake unit (5) in the open position while holding the rest of the brake units (5) in the closed position; and ramping (102;102') up a test torque with the motor (3), or alternatively ramping (102') down a test torque with the motor (3); and monitoring (103) movement of a component of the hoisting machine during the ramping up or down (102;102'), respectively, said component preferably being the rotor of the motor (3) or the drive member (4); and detecting (104) starting of movement of the component or that amount of movement exceeds a limit amount during the ramping up or down (102;102'), respectively; and registering (105) the magnitude of the test torque (Ttest) at the moment when the movement started or exceeded a limit amount. The method comprises repeating (200) the performing (100) a test sequence one or more times with a new test configuration, the combinations of brake units (5) held in open position and in closed position being different in the test sequences; and determining (300) an individual braking torque (Ti) of each individual brake unit (5) based on the registered magnitudes of test torques (Ttest), and determining (400) and/or predicting condition of the brake units (5) based on said individual braking torques. The invention also relates to an elevator arrangement (1) implementing the method.

Fig. 1



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Description

Field of the invention

[0001] The invention relates to monitoring the condition of the brakes of an elevator arrangement. The elevator arrangement is in particular suitable for vertically transporting passengers and/or goods.

Background of the invention

[0002] Elevators typically have an elevator car and a counterweight, which are interconnected by a hoisting roping passing around a drive member, which drive member is rotatable by a motor. The drive member can be a traction sheave, for example. These movable units of the elevator are usually on opposite sides of the drive member such that when one is moved upwards by rotating the drive member, the other moves downwards. The balance situation depends on prevailing load of the car, position of the car as well as design choices made with regard to weight difference of an empty elevator car and the counterweight.

[0003] The motor can be used for producing or resisting rotation of the drive member. In practice, the motor can produce torque on the drive member, which torque can urge the drive member to rotate or resist rotation of the drive member, depending on situation and prevailing deviation from balance. Thus, the direction of the motor torque may sometimes be opposite to the rotation direction and sometimes the rotation direction.

[0004] Elevators typically also have electromechanical brakes (also referred to as brake units), which can apply braking force directly to the drive member or to some other rotatable component of the elevator hoisting machinery, which is connected to the drive member, such as to a motor shaft or a brake disc, for example. The braking force produces a torque on the component on which they act on, which torque resists rotation of the component.

[0005] There are traditionally two separate brakes in a hoisting machinery. However, recently multi-brake hoisting machineries, i.e. machineries with more than two, such as three or four brakes have been introduced. They shall be dimensioned to stop and hold standstill an elevator car with an overload. If one brake fails, for safety reasons the remaining ones should still stop and hold an elevator car with suitable safety margin.

[0006] Due to being highly relevant to safety of the elevator, working condition of the hoisting machinery brakes needs to be monitored.

[0007] Document WO2023/280400A1 discloses a method for determining sufficiency of braking effect of a multi-brake hoisting machinery. Brake test is conducted such that one brake is opened at a time while other brakes are kept engaged, and a test torque is applied. If elevator car movement is detected, signal indicating degraded condition of one or more brakes is generated. This test informs whether the minimum requirement is fulfilled that in the event that one brake is out of order, the others can prevent movement without it.

[0008] A drawback of prior solutions has been that they provide little information of a multi-brake hoisting machinery. The information obtained does not effectively enable accurate, well focused and early maintenance, such as preventive maintenance. Thus, there is a need for enhanced methods for testing and / or predicting working condition of the brakes of a multi-brake elevator hoisting machinery.

Brief description of the invention

[0009] The object of the invention is to introduce an improved method and elevator arrangement whereby condition of an elevator hoisting machinery can be tested and/or predicted.

[0010] An object is particularly to introduce a solution by which it can be determined what is the actual braking torque each individual brake unit of a multi-brake elevator hoisting machinery is capable of. An object is further to introduce a solution facilitating determining and/or forecasting sufficiency of the braking effect of the individual brake unit with an improved accuracy.

[0011] It is brought forward a new method for monitoring brakes of a multi-brake hoisting machinery of an elevator arrangement, which hoisting machinery comprises a motor, a drive member rotatable by the motor, and three or more brake units for braking rotation of the drive member, each brake unit being shiftable between open (i.e. non-braking) position I and closed (i.e. braking) position II. The method comprises performing a test sequence, wherein the test sequence comprises:

holding at least one brake unit in the open position while holding the rest of the brake units in the closed position; and
ramping up a test torque with the motor, or alternatively ramping down a test torque with the motor; and
monitoring movement of a component, which is preferably a component of the hoisting machine, during the ramping up or down, respectively, said component preferably being the rotor of the motor or the drive member; and
detecting starting of movement of the component or that amount of movement exceeds a limit amount during the

ramping up or down, respectively; and
registering the magnitude of the test torque (Ttest) at the moment when the movement started or exceeded a limit amount.

[0012] After this, the method comprises

repeating the performing a test sequence one or more times with a new test configuration, the combinations of brake units held in open position and in closed position being different in the test sequences; and

determining an individual braking torque (Ti) of each individual brake unit based on the registered magnitudes of test torques (Ttest), and

determining and/or predicting condition of the brake units based on said individual braking torques.

[0013] With this kind of solution one or more of the above-mentioned objects can be facilitated. By means of the individual braking torques obtained this way, condition of the brake units of the multi-brake elevator hoisting machinery may be determined with an increased accuracy. It may also be possible to predict possible changes in said working condition, for example by analyzing a trend of the braking torques registered during consecutive test events. This prediction may also be carried out remotely, for example by means of a cloud computing system, and results may be utilized when scheduling maintenance visits to elevator sites.

[0014] Preferable further details of the method are introduced in the following, which further details can be combined with the method individually or in any combination.

[0015] In a preferred embodiment, each said repeating comprises changing the test configuration.

[0016] In a preferred embodiment, in said changing the test configuration, the test configuration is changed such that at least one brake unit that was held in closed position II during the previous test sequence is held in open position I in the repeated test sequence and/or such that at least one brake unit that was held in open position I during the previous test sequence is held in closed position II in the repeated test sequence.

[0017] In a preferred embodiment, the test sequence comprises:

holding one brake unit in the open position while holding the rest of the brake units in the closed position, or alternatively holding all but one brake units in the open position while holding one of the brake units in the closed position; and

ramping up a test torque with the motor, or alternatively ramping down a test torque with the motor; and

monitoring movement of a component, which is preferably a component of the hoisting machine, during the ramping up or down, respectively, said component preferably being the rotor of the motor or the drive member; and

detecting starting of movement of said component or that amount of movement exceeds a limit amount during the ramping up or down, respectively; and

registering the magnitude of the test torque (Ttest) at the moment when the movement started or exceeded a limit amount.

[0018] In a preferred embodiment, the test sequences are repeated until every individual brake unit has been held alone in the open position during a ramping, or until every individual brake unit has been held alone in a closed position during a ramping, respectively.

[0019] In a preferred embodiment, said determining condition of the brake units comprises comparing the individual braking torque of each individual brake unit with at least one limit.

[0020] In a preferred embodiment, said determining braking torque of each individual brake unit based on the registered magnitudes of test torques comprises calculating the braking torque of each individual brake unit.

[0021] In a preferred embodiment, the test sequence comprises holding one brake unit in a open position while holding the rest of the brake units in a closed position and said calculating the torque of each individual brake unit is performed using equation:

$$T_i = \frac{1}{n-1}\sum_{j=1}^{n} T_j - T_{i\,\mathrm{(open)}}$$

wherein

T_j = sum of magnitudes of all test torques (j ; j = 1..n); and
Ti(open) = magnitude of single test torque, when brake unit i was held open; and
T_i = braking torque of a single brake unit (i ; i = 1..n).

[0022] In a preferred embodiment, the method is performed automatically by a controlling and monitoring system, wherein the controlling and monitoring system preferably comprises one or more microprocessors and a memory storing a computer program for performing one or more steps of the method, preferably in particular the steps (100, 200, 300 and 400).
[0023] In a preferred embodiment, in each said ramping, a gradually increasing or reducing test torque is exerted by the motor on the drive member.
[0024] In a preferred embodiment, in said ramping up a test torque, test torque is increased gradually, in particular from zero torque or an initial non-zero torque (Tinitial1).
[0025] In a preferred embodiment, in said ramping down a test torque, torque is reduced gradually from an initial non-zero torque (Tinitial2).
[0026] In the preferred embodiment, said gradually increasing or reducing torque is performed in stepwise manner. After each stepwise increase, a constant test torque is exerted for a period, the period preferably being 20-200 ms, more preferably 50-150 ms, most preferably about or exactly 100 ms.
[0027] In a preferred embodiment, the method comprises, when starting the test sequence, exerting an initial torque (Tinitial) by the motor on the drive member against opposite direction torque exerted on the drive member by components external to hoisting machinery , in particular by a hoisting roping suspending movable elevator units, in particular a car and counterweight, in particular for counteracting at least partially said opposite direction torque and for preventing with the initial torque (Tinitial) rotation of the drive member already when starting the test sequence.
[0028] In a preferred embodiment, the registering comprises storing the magnitude of the test torque (Ttest) into a memory of a controlling and monitoring system of the elevator arrangement.
[0029] In a preferred embodiment, the brake units are operable separately from each other. More specifically, each brake unit preferably comprises an actuator operable separately from actuators of other brake units.
[0030] In a preferred embodiment, each said brake unit comprises a brake member movable in closed position where it is in contact with a part of the hoisting machinery which part is rotatable together with the drive member, and to an open position where it is out of contact with said part.
[0031] In a preferred embodiment, the method comprises performing a reference test sequence where steps (101-105) similar to those of a test sequence, are performed such that in the holding (step 101) all the brake units are held in closed position. Thus, the magnitude of a maximum torque can be registered for being used as reference in a following determination step.
[0032] It is also brought forward a new elevator arrangement, which elevator arrangement comprises a multi-brake elevator hoisting machinery comprising

a motor;
a drive member rotatable by the motor; and
three or more brake units for braking rotation of the drive member, wherein each brake unit is shiftable between open (i.e. non-braking) position I and closed (i.e. braking) position II; and
wherein the elevator arrangement further comprises a controlling and monitoring system configured to execute the method as described anywhere above or in any of the claims of the application.

[0033] With this kind of solution one or more of the above-mentioned objects can be facilitated.
[0034] Preferable further details of the elevator arrangement are introduced in the following, which further details can be combined with the elevator arrangement individually or in any combination.
[0035] In a preferred embodiment, the controlling and monitoring system is configured to perform a test sequence, and as part of the test sequence:

to hold at least one brake unit in the open position while holding the rest of the brake units in the closed position; and
to ramp up a test torque with the motor, or alternatively ramp down a test torque with the motor; and
monitor movement of a component, which is preferably a component of the hoisting machine, during the ramping up or down, respectively, said component preferably being the rotor of the motor or the drive member; and
detect starting of movement of the component or that amount of movement exceeds a limit amount during the ramping up or down, respectively; and
register the magnitude of the test torque (Ttest) at the moment when the movement started or exceeded a limit amount;

wherein the controlling and monitoring system is further configured to

repeat the test sequence one or more times with a new test configuration, the combinations of brake units held in open position and in closed position being different in the test sequences; and

to determine an individual braking torque of each individual brake unit based on the registered magnitudes of test torques (Ttest), and

to determine and/or predict condition of the brake units based on said individual braking torques.

[0036] In a preferred embodiment, the controlling and monitoring system is configured as part of the test sequence:

to hold one brake unit in the open position while holding the rest of the brake units in the closed position, or alternatively to hold all but one brake units in the open position while holding one of the brake units in the closed position; and

to ramp up a test torque with the motor, or alternatively to ramp down a test torque with the motor.

[0037] In a preferred embodiment of the method or the elevator arrangement, the elevator arrangement comprises:

a hoisting roping passing around the drive member; and

a first movable unit and a second movable unit, one of them being an elevator car and the other preferably a counterweight, which movable units are interconnected by the hoisting roping, and suspended by the roping on opposite sides of the drive member, in particular such that when the drive member rotates in its first direction the first movable unit is moved upwards and the second movable unit is moved downwards.

[0038] In a preferred embodiment of the method or the elevator arrangement, the controlling and monitoring system is configured to perform automatically one or more steps of the method as described anywhere above or in any of the claims of the application, preferably in particular the steps 100, 200, 300 and 400.

[0039] In a preferred embodiment of the method or the elevator arrangement, the controlling and monitoring system comprises one or more microprocessors and a memory storing a computer program for performing one or more steps of the method as described anywhere above or in any of the claims of the application, preferably in particular the steps 100, 200, 300 and 400.

[0040] In a preferred embodiment of the method or the elevator arrangement, the whole time of the test sequences, the elevator arrangement is out of use for transporting passengers and/or goods.

[0041] In a preferred embodiment of the method or the elevator arrangement, the motor is an electric motor.

[0042] In a preferred embodiment of the method or the elevator arrangement, the elevator arrangement is for vertically transporting passengers and/or goods inside a car thereof.

Brief description of the drawings

[0043] In the following, the present invention will be described in more detail by way of example and with reference to the attached drawings, in which

Figure 1 illustrates schematically an elevator arrangement when performing a a test sequence of a method according to a first embodiment.

Figure 2 illustrates a torque curve of the elevator motor realized when performing a test sequence of a method according to a first embodiment as illustrated in Figure 1.

Figure 3 illustrates schematically an elevator arrangement when performing a a test sequence of a method according to a second embodiment.

Figure 4 illustrates a torque curve of the elevator motor realized when performing a test sequence of a method according to the second embodiment as illustrated in Figure 1.

Figure 5 illustrates further details of the steps of the method.

Detailed description

[0044] Figures 1 and 3 illustrate an elevator arrangement 1 according to an embodiment, which elevator arrangement comprises a multi-brake elevator hoisting machinery 2 comprising a motor 3; a drive member 4 rotatable by the motor 3. The motor 3 is an electric motor. The hoisting machinery 2 further comprises three or more brake units 5 for braking rotation of the drive member 4. Here, there are three brake units 5, but alternatively there could be more, such as four or five brake units 5, for example. Each brake unit 5 is shiftable between open (i.e. non-braking) position I and closed (i.e. braking) position II. The brake units 5 are illustrated schematically. The details of the actuating means of the brake units 5 are not illustrated. In the preferred embodiments, when a brake unit 5 is in the closed position II, a brake member 5a of the brake unit 5 is in contact with a part 4a of the hoisting machinery 2 which part 4a is rotatable together with the drive member 4, and when a brake unit 5 is in the open position I, a brake member 5a of the brake unit 5 is out of contact with the part 4a.

[0045] The elevator arrangement 1 comprises a hoisting roping 6 passing around the drive member 4; and a first movable unit 7 and a second movable unit 8, one of them being an elevator car and the other preferably a counterweight, which movable units 7,8 are interconnected by the hoisting roping 6, and suspended by the hoisting roping 6 on opposite sides of the drive member 4, in particular such that when the drive member 4 rotates in its first direction the first movable unit 7 is moved upwards and the second movable unit 8 is moved downwards.

[0046] The elevator arrangement 1 further comprises a controlling and monitoring system 12. The controlling and monitoring system 12 is connected to the hoisting machinery 2, in particular such that it can control the motor and the brake units 5 thereof. The controlling and monitoring system 12 comprises an elevator control 10 for controlling the brake units 5 and the motor 3. In the illustrated embodiment, the controlling and monitoring system 12 comprises a remote monitoring unit or system 11 for monitoring the hoisting machinery 2 over a data bus, but this is not necessary since this function could be alternatively performed by the elevator control 11, and thereby locally.

[0047] The controlling and monitoring system 12 is configured to execute a method for monitoring brakes of a multi-brake hoisting machinery 2 of an elevator arrangement 1 as will be described hereinafter.

[0048] Figure 1 illustrates the elevator arrangement 1 executing the method according to a first embodiment, and Figure 2 illustrates an exemplary torque curve realized in the method according to the first embodiment. Figure 3 illustrates the elevator arrangement 1 executing the method according to a second embodiment, and Figure 4 illustrates an exemplary torque curve realized in the method according to the first embodiment. Figure 5 illustrates steps of the method.

[0049] In the first embodiment of the method illustrated in Figures 1 and 2, the method for monitoring brakes of a multi-brake hoisting machinery 2 of an elevator arrangement 1 comprises performing a test sequence 100 where the test sequence comprises holding 101 at least one brake unit 5, which is in the preferred embodiment only one brake unit 5, in the open position while holding the rest of the brake units 5 in the closed position.

[0050] The test sequence further comprises ramping 102 up a test torque with the motor 3, in particular during said holding 101. The ramping is illustrated in Figure 2.

[0051] In said ramping 102 up a test torque, a gradually increasing test torque is exerted by the motor 3 on the drive member 4. In said ramping 102 up a test torque, the test torque is increased gradually, in particular from zero torque or an initial non-zero torque Tinitial1. This is preferably implemented such that the torque reference of the motor 3 is increased gradually, preferably stepwise.

[0052] In the preferred embodiment, the test torque is increased gradually in stepwise manner as visible in Figure 2. After each stepwise increase, a constant test torque is exerted for a period by the motor 3 on the drive member 4, the period preferably being 20-200 ms, more preferably 50-150 ms, most preferably about or exactly 100 ms. Within this kind of period, movement is likely to occur if the prevailing test torque exceeds the holding ability of the closed brake units 5, and this kind of period is long enough to enable detection of the movement reliably yet the rotation is unlikely to reach a harmfully high speed.

[0053] The test sequence further comprises monitoring 103 movement of a component, which is preferably a component of the hoisting machine 2, during the ramping 102. Said component is preferably the rotor of the motor 3 or the drive member 4.

[0054] The test sequence further comprises detecting 104 starting of movement of said component or that amount of movement exceeds a limit amount during the ramping 102 and registering 105 the magnitude of the test torque Ttest at the moment when the movement started or exceeded a limit amount, respectively.

[0055] In the example illustrated by Figure 2, movement is detected to occur at t=450 ms. At that moment the magnitude of the test torque is illustrated by Ttest. In the test sequence in question, this Ttest is registered, e.g. by storing it into a memory of the controlling and monitoring system 12.

[0056] The method further comprises repeating 200 the performing 100 a test sequence one or more times with a new test configuration, the combinations of brake units 5 held in open position and in closed position being different in the test sequences. By said repeating 200, data is collected of different test configurations.

[0057] After said repeating 200, the method comprises determining 300 an individual braking torque Ti of each individual brake unit 5 based on the registered magnitudes of test torques Ttest.

[0058] The method further comprises determining 400 condition of the brake units 5 and/or predicting condition of the brake units 5 based on said individual braking torques Ti.

[0059] In the embodiment of Figures 1 and 2, the test sequences 100 are repeated [in said repeating 200] until every individual brake unit 5 has been held alone in the open position during a ramping 102.

[0060] In general, each repeated test sequence can look otherwise similar to what is disclosed in Figure 2, but the magnitude of the Ttest can be different depending on the condition of the individual brake units 5 being held in closed position.

[0061] In the embodiment of Figures 1 and 2, each said repeating 200 comprises changing the test configuration. In the embodiment of Figures 1 and 2, said changing the test configuration comprises opening at least one brake unit 5 that was held in closed position II during the previous test sequence 100 and closing at least one brake unit 5 that was held in open position I during the previous test sequence 100.

[0062] Said determining 300 braking torque of each individual brake unit 5 based on the registered magnitudes of test torques comprises calculating the braking torque of each individual brake unit 5. In this embodiment, the magnitude of the test torque Ttest indicates a total braking torque without any braking effect contributed by the single brake unit 5 that is held open. Repeated test sequences in different test configurations provide enough information to calculate the braking torque Ti of each individual brake unit 5. Thus, by repeating test sequences so that the combinations of brake units 5 held in open position and in closed position are different in the test sequences, enough data can be collected so that by relatively simple mathematics braking torques of individual brake units 5 can be calculated.

[0063] In the embodiment of Figure 1, where the test sequence comprises holding one brake unit 5 in a open position while holding the rest of the brake units 5 in a closed position, it is preferred that said calculating the torque of each individual brake unit 5 is performed using equation:

$$T_i = \frac{1}{n-1}\sum_{j=1}^{n} T_j - T_{i\,\mathbf{(open)}}$$

wherein

T_j = sum of magnitudes of all test torques (j ; j = 1..n); and
Ti(open) = magnitude of single test torque, when brake unit i was held open; and
T_i = braking torque of a single brake unit (i ; i = 1..n).

[0064] In the embodiment of Figure 1, for example when three brakes are tested (n = 3), three brake sequences are performed. In each sequence one brake held in open position a time while the rest are held in closed position. In each test sequence a different brake unit 5 is held in open position. The sum M_j for all brakes 1, 2, 3: [120 (M_1); 110 (M_2); 100 (M_3)]. The individual braking torque M_2 of brake 2, (i = 2) now comes from the equation 1 as follows:

$$T_2 = \frac{1}{3-1}\sum_{j=1}^{3} T_j - T_{2\,\mathbf{(open)}}$$

$$\Rightarrow T_2 = \frac{1}{3-1}(120+110+100) - 110 = \frac{330}{2} - 110 = 165 - 110 = 55$$

[0065] If the test sequences are performed in the method in an unbalanced test situation, i.e. in a situation where torque is exerted on the drive member 4 by components 6,7,8 external to hoisting machinery 2, such as in particular by a hoisting roping 6 suspending movable elevator units 7,8, e.g. a car 7 and counterweight 8, this torque can be taken into account in the calculation.

[0066] In the second embodiment of the method illustrated in Figures 2 and 3, the method for monitoring brakes of a multi-brake hoisting machinery 2 of an elevator arrangement 1 comprises performing 100 a test sequence where the test sequence comprises holding 101 at least one brake unit 5, which is in the preferred embodiment all but one brake units 5, in the open position while holding the rest of the brake units 5, which is in the preferred embodiment only one brake unit 5, in the closed position.

[0067] The test sequence further comprises ramping 102' down a test torque with the motor 3, in particular during said holding 101. The ramping 102' down is illustrated in Figure 4.

[0068] In said ramping 102' down a test torque, a gradually reducing test torque is exerted by the motor 3 on the drive member 4. In said ramping 102' down a test torque, the test torque is reduced gradually, in particular from an initial non-zero torque Tinitial2. This is preferably implemented such that the torque reference of the motor 3 is reduced gradually, preferably stepwise.

[0069] In the preferred embodiment, the test torque is reduced gradually in stepwise manner as visible in Figure 4.

After each stepwise reduction, a constant test torque is exerted for a period by the motor 3 on the drive member 4, the period preferably being 20-200 ms, more preferably 50-150 ms, most preferably about or exactly 100 ms. Within this kind of period, movement is likely to occur if the prevailing test torque exceeds the holding ability of the closed brake units 5, and this kind of period is long enough to enable detection of the movement reliably yet the rotation is unlikely to reach a harmfully high speed.

[0070] An initial non-zero initial torque Tinitial2 is needed in most cases for holding the car and hoisting roping still, because in most elevators there is a weight difference between an empty elevator car and the counterweight, which together with possible additional unbalance of a hoisting roping (e.g. caused by car position-based unbalance of roping) might exceed the ability of the small number of brake units 5 (here only one) in closed position. Thereby, a substantial initial torque at the start of the test sequence may be needed for preventing movement due to said weight difference immediately after opening of the brake units 5 which are to be held during the test sequence.

[0071] In the second embodiment, the method comprises, when starting each test sequence 100, exerting an initial [non-zero] torque Tinitial by the motor 3 on the drive member 4 against opposite direction torque (also referred to as the external torque) exerted on the drive member 4 by components 6,7,8 external to hoisting machinery 2, in particular by a hoisting roping 6 suspending movable elevator units 7,8, in particular a car 7 and counterweight 8, in particular for counteracting at least partially said opposite direction torque and for preventing with the initial torque Tinitial rotation of the drive member 4 already when starting the test sequence 100.

[0072] The test sequence further comprises monitoring 103 movement of a component of the hoisting machine 2 during the ramping 102', said component preferably being the rotor of the motor 3 or the drive member 4.

[0073] The test sequence further comprises detecting 104 starting of movement of said component or that amount of movement of said component exceeds a limit amount during the ramping 102' and registering 105 the magnitude of the test torque Ttest at the moment when the movement started or exceeded a limit amount, respectively. In the example illustrated by Figure 2, movement is detected to start at t=450 ms. At that moment the magnitude of the test torque is illustrated by Ttest. In the test sequence in question, this Ttest is registered, e.g. by storing it into a memory of the controlling and monitoring system 12.

[0074] The method further comprises repeating 200 the performing 100 a test sequence one or more times with a new test configuration, the combinations of brake units 5 held in open position and in closed position being different in the test sequences. By said repeating 200, data is collected of different test configurations.

[0075] After said repeating 200, the method comprises determining 300 an individual braking torque Ti of each individual brake unit 5 based on the registered magnitudes of test torques Ttest.

[0076] The method further comprises determining 400 condition of the brake units 5 and/or predicting condition of the brake units 5 based on said individual braking torques Ti.

[0077] In the embodiment of Figures 3 and 4, the test sequences 100 are repeated [in said repeating 200] until every individual brake unit 5 has been held alone in the closed position during a ramping 102' down of a test sequence.

[0078] In general, each repeated test sequence can look otherwise similar to what is disclosed in Figure 2, but the magnitude of the Ttest can be different depending on the condition of the individual brake unit 5 being held in closed position.

[0079] In the embodiment of Figures 3 and 4, each said repeating 200 comprises changing the test configuration. In the embodiment of Figures 3 and 4, said changing the test configuration comprises opening a brake unit 5 that was held closed during previous test sequence 100 and closing a brake unit 5 that was held open during previous test sequence 100.

[0080] Said determining 300 braking torque of each individual brake unit 5 based on the registered magnitudes of test torques Ttest may comprise calculating the braking torque of each individual brake unit 5. In this second embodiment, the magnitude of the test torque Ttest gives a torque value for an individual brake unit 5 which value can, in principle, directly be considered as the braking torque of each individual brake unit 5. However, it may be advantageous to eliminate the effect of an unbalance, in cases where the test sequence in question was/is performed in the method in an unbalanced test situation as described elsewhere in the application. In such a case, the calculating could involve calculating the difference of each magnitude of test torque Ttest and the external torque prevailing during the test sequence. This is preferable in the case of the second embodiment for instance where the external torque is directed oppositely relative to the test torque.

[0081] In general, in the method, said determining condition of the brake units 5 can comprise comparing the individual braking torque Ti of each individual brake unit 5 with at least one limit.

[0082] In general, the method is preferably performed automatically by a controlling and monitoring system 12. The controlling and monitoring system 12 preferably comprises one or more microprocessors and a memory storing a computer program for performing steps of the method. The controlling and monitoring system 12 may comprise an elevator control unit 10 and a remote monitoring unit 11, for example, in which case part of the steps of the method can be performed by the elevator control unit 10 and part of the steps of the method can be performed by the remote monitoring unit 11.

[0083] In general, the limit amount of movement of a component is preferably an amount of movement corresponding to displacement distance, which is within range 1-10 mm, preferably less than 5 mm, most preferably 1-3 mm. Hereby, the limit amount of movement corresponds to a relatively small amount of movement, which is enough to reliably indicate that the test torque has exceeded the braking torque of the closed brake units 5.

[0084] As mentioned, an elevator arrangement 1 according to an embodiment of the invention is illustrated in Figures 1 and 3. The elevator arrangement 1 comprises a controlling and monitoring system 12 configured to execute the method as described anywhere above referring to Figures 1-4. Thus, the controlling and monitoring system 12 is configured to perform a test sequence 100, and as part of the test sequence 100:

to hold at least one brake unit 5 in the open position I while holding the rest of the brake units 5 in the closed position II; and
to ramp up a test torque with the motor 3, or alternatively ramp down a test torque with the motor 3; and
monitor movement of a component, which is preferably a component of the hoisting machine, during the ramping up or down, respectively, said component preferably being the rotor of the motor 3 or the drive member 4; and
detect starting of movement of the component or that amount of movement exceeds a limit amount during the ramping up or down, respectively; and
register the magnitude of the test torque Ttest at the moment when the movement started or exceeded a limit amount.

[0085] The controlling and monitoring system 12 is further configured to

repeat the test sequence 100 one or more times with a new test configuration, the combinations of brake units 5 held in open position and in closed position being different in the test sequences; and
to determine an individual braking torque Ti of each individual brake unit 5 based on the registered magnitudes of test torques Ttest, and
to determine and/or predict condition of the brake units 5 based on said individual braking torques.

[0086] Preferably, the controlling and monitoring system 12 is more specifically preferably configured, as part of the test sequence:

to hold one brake unit 5 in the open position while holding the rest of the brake units 5 in the closed position, or alternatively to hold all but one brake units 5 in the open position while holding one of the brake units 5 in the closed position; and
to ramp 102 up a test torque with the motor 3, or alternatively to ramp 102' down a test torque with the motor 3.

[0087] The controlling and monitoring system 12 is configured to perform automatically the steps of the method, preferably in particular the steps 100, 200, 300 and 400 as described earlier above. The controlling and monitoring system 12 preferably comprises one or more microprocessors and a memory storing a computer program for performing steps of the method, preferably in particular the steps 100, 200, 300 and 400 as described earlier above.

[0088] In general, in the method the monitoring 103 movement of a component of the hoisting machine 2 during the ramping up or down 102;102' can be done e.g. by any known way. This monitoring preferably comprises measuring the movement of the component by a measuring device (not shown), which measuring device may be comprised in the hoisting machinery 2. The measuring device can be for instance any kind of a sensor, possibly in particular an encoder. The measuring device preferably measures angle and/or speed of movement of said component.

[0089] In general, the part 4a of the hoisting machinery 2 rotating together with the drive member 4 is preferably an integral part of the drive member 4 or a part rigidly connected to it.

[0090] In general, the term "multi-brake elevator hoisting machinery" refers to a hoisting machinery having more than two, such as three or four or even more individual brake units.

[0091] In general, the brake units are operable separately from each other. Each said brake unit 5 preferably comprises an actuator (not shown) for moving the brake member 5a, such as a brake pad, of the brake unit 5. The actuator is preferably an electromechanics device, such as a solenoid or electromagnet. As it is common in elevators, the actuator is preferably able to move, when actuated, the brake member 5a of the brake unit 5 against a spring force towards open position I. In the step of holding the brake unit 5 in open position I, the brake member 5a is preferably held by aid of the force of the actuator against the spring force in open position I and in the step of holding the brake unit 5 in closed position II, the brake member 5a is preferably held by aid of the spring force in the closed position II. Each said holding can be realized by the controlling and monitoring system 12 by controlling of the actuator.

[0092] In general, it is preferable that the method comprises initiating the testing if at least one preset criteria is fulfilled. Such criteria may be, for example, an empty elevator car being located at a test location. Another criteria may be e.g. time of the day - test may be scheduled at the time of low traffic, such as during night time for example. After said initiating the test sequence 100 is performed, followed by the steps 200, 300 and 400 of the method as described.

[0093] In general, in the embodiments, examples of different test configurations have been presented. However it is to be understood, that number of individual brakes open/closed during the test may also vary from what is disclosed by examples. Repeated test sequences in different test configurations provide enough information to calculate the braking torque Ti of each individual brake unit 5. By repeating, enough data can be collected so that by relatively simple mathematics braking torques of individual brake units can be calculated also with different combinations than what are shown by way of illustrated examples in the application. For example, it is possible to determine individual braking torques with repeated test sequences where in the test configurations there are 2 brake units held in open position and 2 in closed position.

[0094] In general, if one wants to simplify the calculation, the method can comprise performing a reference test sequence where the steps 101-105 are performed such that in the step 101 all the brake units are held in closed position. Thus, the magnitude of a maximum torque can be registered for being used as reference in a following determination step. Thus, step 300, in particular a calculation process thereof, can be further simplified since the difference between said magnitude of a maximum torque and the magnitude of each test torque caused by the open brake unit(s) reveals the effect of the brake units held open.

[0095] In general, as mentioned, the component movement of which is monitored in said monitoring 103 during the ramping 102; 102', is preferably a component of the hoisting machine 2. However, this is not necessary, because the component could also be some other movable component of the elevator arrangement 1, such as a rope, the movable unit 7 or 8 or a component of any one of these.

[0096] It is to be understood that the above description and the accompanying Figures are only intended to teach the best way known to the inventors to make and use the invention. It will be apparent to a person skilled in the art that the inventive concept can be implemented in various ways. The above-described embodiments of the invention may thus be modified or varied, without departing from the invention, as appreciated by those skilled in the art in light of the above teachings. It is therefore to be understood that the invention and its embodiments are not limited to the examples described above but may vary within the scope of the claims.

Claims

1. A method for monitoring brakes of a multi-brake hoisting machinery (2) of an elevator arrangement (1), which hoisting machinery (2) comprises a motor (3), a drive member (4) rotatable by the motor (3), and three or more brake units (5) for braking rotation of the drive member (4), each brake unit (5) being shiftable between open position (I) and closed position (II), the method comprising

- performing a test sequence (100), wherein the test sequence comprises:

  holding (101) at least one brake unit (5) in the open position (I) while holding the rest of the brake units (5) in the closed position (II); and
  ramping (102) up a test torque with the motor (3), or alternatively ramping (102') down a test torque with the motor (3); and
  monitoring (103) movement of a component, which is preferably a component of the hoisting machine (2), during the ramping up or down (102;102'), respectively, said component preferably being the rotor of the motor (3) or the drive member (4); and
  detecting (104) starting of movement of the component or that amount of movement exceeds a limit amount during the ramping up or down (102;102'), respectively; and
  registering (105) the magnitude of the test torque (Ttest) at the moment when the movement started or exceeded a limit amount; and

- repeating (200) the performing a test sequence (100) one or more times with a new test configuration, the combinations of brake units (5) held in open position (I) and in closed position (II) being different in the test sequences; and
- determining (300) an individual braking torque (Ti) of each individual brake unit (5) based on the registered magnitudes of test torques (Ttest), and
- determining (400) and/or predicting condition of the brake units (5) based on said individual braking torques (Ti).

2. A method according to claim 1, wherein each said repeating (200) comprises changing the test configuration.

3. A method according to any of the preceding claims, wherein in said changing the test configuration, the test configuration is changed such that at least one brake unit (5) that was held closed during previous test sequence (100) is held open in the repeated test sequence and/or such that at least one brake unit (5) that was held open during previous test sequence (100) is held closed in the repeated test sequence (100).

4. A method according to any of the preceding claims, wherein the test sequence (100) comprises:

holding one brake unit (5) in the open position (I) while holding the rest of the brake units (5) in the closed position (II), or alternatively holding all but one brake units (5) in the open position (I) while holding one of the brake units (5) in the closed position (II); and
ramping (102) up a test torque with the motor (3), or alternatively ramping (102') down a test torque with the motor (3); and
monitoring movement of a component, which is preferably a component of the hoisting machine (2), during the ramping up or down (102;102'), respectively, said component preferably being the rotor of the motor (3) or the drive member (4); and
detecting starting of movement of said component or that amount of movement exceeds a limit amount during the ramping up or down (102;102'), respectively; and
registering the magnitude of the test torque (Ttest) at the moment when the movement started or exceeded a limit amount.

5. A method according to any of the preceding claims, wherein the test sequences (100) are repeated until every individual brake unit (5) has been held alone in the open position (I) during a ramping (102), or until every individual brake unit (5) has been held alone in a closed position (II) during a ramping (102'), respectively.

6. A method according to any of the preceding claims, wherein said determining condition of the brake units (5) comprises comparing the individual braking torque (Ti) of each individual brake unit (5) with at least one limit.

7. A method according to any of the preceding claims, wherein said determining individual braking torque (Ti) of each individual brake unit (5) based on the registered magnitudes of test torques (Ttest) comprises calculating the individual braking torque (Ti) of each individual brake unit (5).

8. A method according to any of the preceding claims, wherein the test sequence (100) comprises holding one brake unit (5) in a open position (I) while holding the rest of the brake units (5) in a closed position (II) and said calculating the individual torque (Ti) of each individual brake unit (5) is performed using equation:

$$T_i = \frac{1}{n-1} \sum_{j=1}^{n} T_j - T_{i\,\mathrm{(open)}}$$

wherein

T_j = sum of magnitudes of all test torques (j ; j = 1..n); and
Ti(open) = magnitude of single test torque, when brake unit i was held open; and
T_i = braking torque of a single brake unit (i ; i = 1..n).

9. A method according to any of the preceding claims, wherein the method is performed automatically by a controlling and monitoring system (12), wherein the controlling and monitoring system (12) preferably comprises one or more microprocessors and a memory storing a computer program for performing steps of the method.

10. A method according to any of the preceding claims, wherein in each said ramping (102;102'), a gradually increasing or reducing, respectively, test torque is exerted by the motor (3) on the drive member (4).

11. A method according to any of the preceding claims, wherein in said ramping (102) up a test torque, test torque is increased gradually, in particular from zero torque or an initial non-zero torque (Tinitial1).

12. A method according to any of the preceding claims, wherein in said ramping (102') down a test torque, torque is reduced gradually from an initial non-zero torque (Tinitial2).

13. A method according to any of the preceding claims 10-12, wherein said gradually increasing or reducing torque is performed in stepwise manner.

14. A method according to any of the preceding claims, wherein the method comprises, when starting the test sequence (100), exerting an initial torque (Tinitial) by the motor (3) on the drive member (4) against opposite direction torque exerted on the drive member (4) by components (6,7,8) external to hoisting machinery (2), in particular by a hoisting roping (6) suspending movable elevator units (7,8), in particular a car (7) and counterweight (8), in particular for counteracting at least partially said opposite direction torque and for preventing with the initial torque (Tinitial) rotation of the drive member (4) already when starting the test sequence (100).

15. An elevator arrangement (1), which elevator arrangement (1) comprises a multi-brake elevator hoisting machinery (2) comprising

a motor (3);
a drive member (4) rotatable by the motor (3); and
three or more brake units (5) for braking rotation of the drive member (4), wherein each brake unit (5) is shiftable between open position (I) and closed position (II); and

wherein the elevator arrangement (1) further comprises a controlling and monitoring system (12) configured to execute the method according to any of the preceding claims 1-14.

Fig. 1

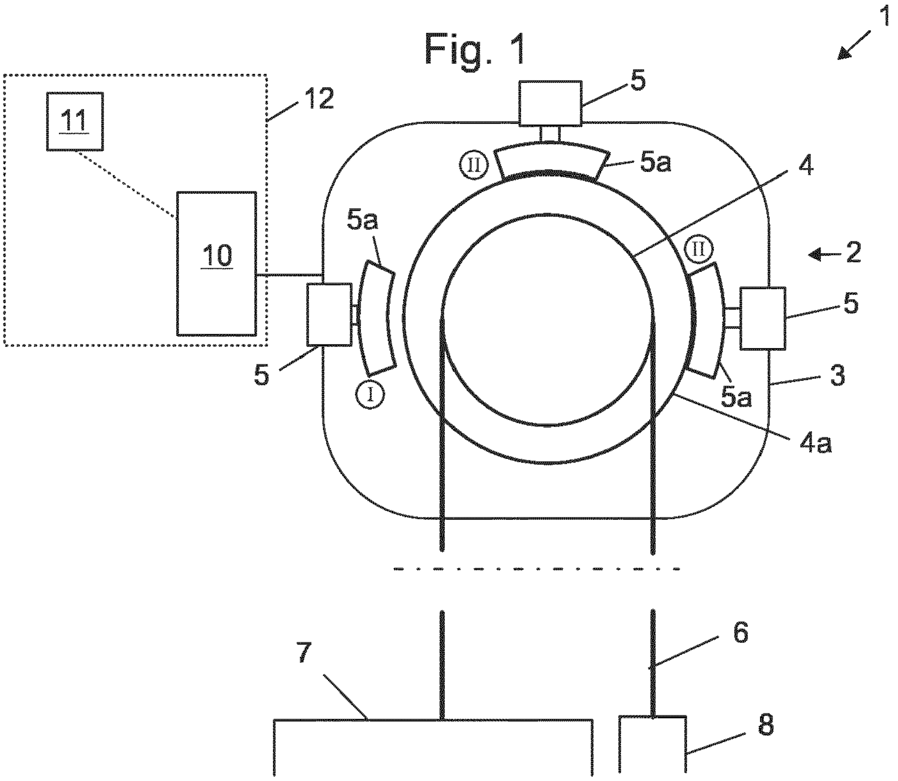

1
12
11
10
5
5a
II
4
2
I
3
4a
6
7
8

Fig. 2

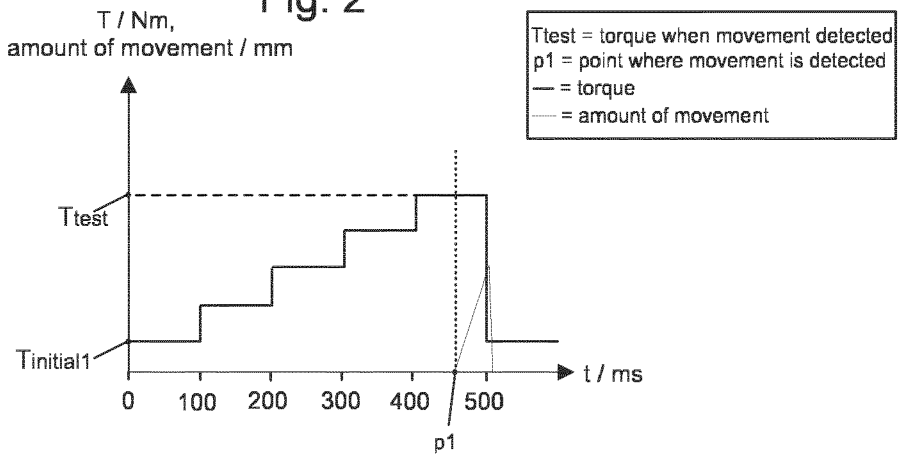
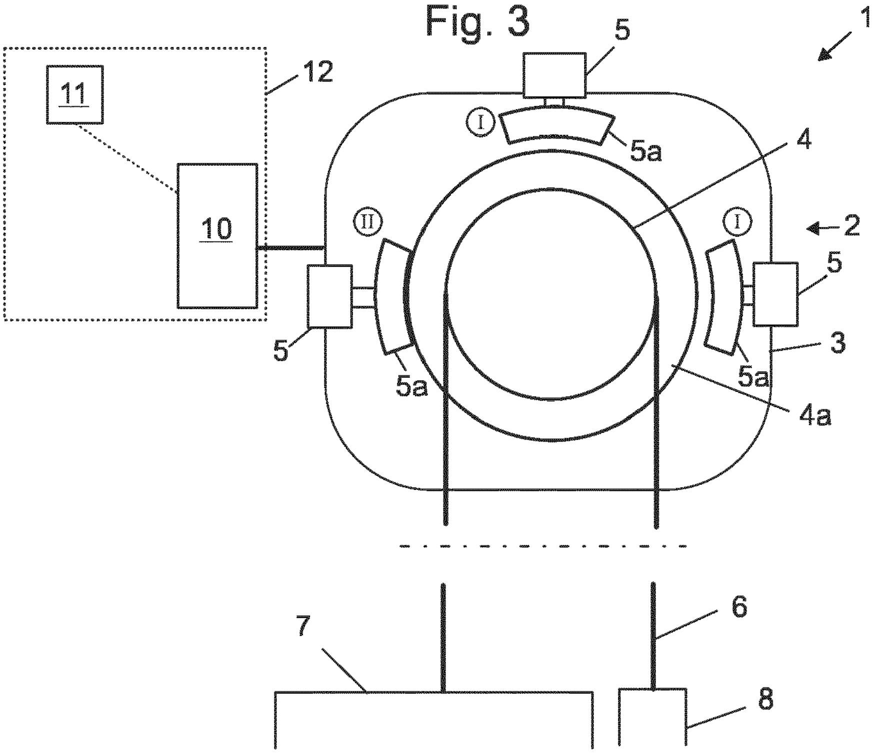
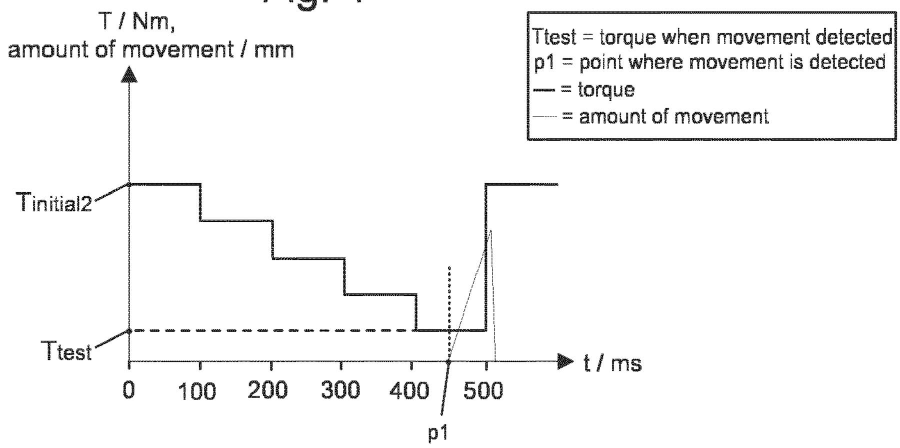

T / Nm,
amount of movement / mm
Ttest = torque when movement detected
p1 = point where movement is detected
— = torque
----- = amount of movement
Ttest
Tinitial1
t / ms
0
100
200
300
400
500
p1

Fig. 3



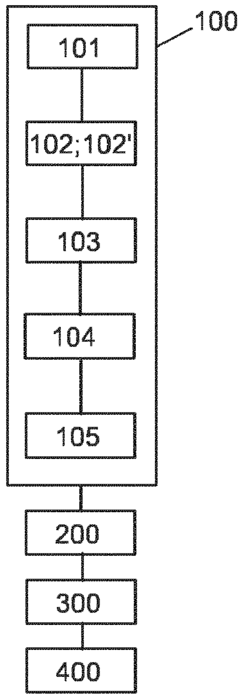
1
2
3
4
4a
5
5a
6
7
8
10
11
12
I
II

Fig. 4



T / Nm,
amount of movement / mm
Ttest = torque when movement detected
p1 = point where movement is detected
= torque
= amount of movement
Tinitial2
Ttest
t / ms
0
100
200
300
400
500
p1

Fig. 5



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EUROPEAN SEARCH REPORT

Application Number
EP 23 16 5390

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X A	EP 1 701 904 B1 (KONE CORP [FI]) 30 November 2011 (2011-11-30) * paragraphs [0022], [0028]; figures 1,2 *	1-7,9-15 8	INV. B66B5/00
A,D	WO 2023/280400 A1 (KONE CORP [FI]) 12 January 2023 (2023-01-12) * paragraphs [0024], [0039], [0043], [0045]; figures 1,2 *	1,15	
A	EP 3 280 666 B1 (INVENTIO AG [CH]) 10 July 2019 (2019-07-10) * paragraphs [0025], [0026]; figures 1,4 *	1,15	
A	TW I 607 949 B (LI AYE ELECTRIC CO LTD [TW]) 11 December 2017 (2017-12-11) * figure 4 *	1,15	

TECHNICAL FIELDS SEARCHED (IPC)

B66B

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
The Hague	15 August 2023	Miklos, Zoltan

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EP 23 16 5390

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15-08-2023

Patent document cited in search report		Publication date	Patent family member(s)			Publication date
EP 1701904	B1	30-11-2011	AT	535482	T	15-12-2011
			CN	1910103	A	07-02-2007
			EP	1701904	A2	20-09-2006
			ES	2373105	T3	31-01-2012
			FI	20040022	A	10-07-2005
			HK	1097505	A1	29-06-2007
			PL	1701904	T3	30-03-2012
			US	2007000735	A1	04-01-2007
			WO	2005066057	A2	21-07-2005
WO 2023280400	A1	12-01-2023	CN	116096664	A	09-05-2023
			EP	4143121	A1	08-03-2023
			US	2023007842	A1	12-01-2023
			WO	2023280400	A1	12-01-2023
EP 3280666	B1	10-07-2019	BR	112017019811	A2	29-05-2018
			CA	2979508	A1	13-10-2016
			CN	107531453	A	02-01-2018
			EP	3280666	A1	14-02-2018
			ES	2745502	T3	02-03-2020
			US	2018134517	A1	17-05-2018
			WO	2016162391	A1	13-10-2016
TW I607949	B	11-12-2017	NONE			

EPO FORM P0459

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REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- WO 2023280400 A1 **[0007]**