

CONTROL APPARATUS OF ELEVATOR

FIELD

Embodiments described herein relate generally to a control apparatus of an elevator, which detects a rope swing due to a shake of a building by an earthquake or
5 a strong wind, and executes switching to a control operation.

BACKGROUND

With an increase in height of a building, the
10 characteristic frequency of the building lowers, and hence a resonance phenomenon tends to occur at a time of occurrence of an earthquake or a strong wind. In this case, if the characteristic frequency of the building coincides with the characteristic frequency of
15 a rope of an elevator which is provided in an elevation shaft, the rope swings greatly due to resonance, and there is a concern that the rope may come in contact with some device in the elevation shaft or walls of the elevation shaft and a so-called "confinement accident"
20 may occur. Incidentally, the rope of the elevator, in this context, refers to a main rope, a governor rope, etc.

To prevent such an accident, elevators in recent years include a safety apparatus called "control
25 operation apparatus". According to this technique, when a building shakes, the safety apparatus detects a rope swing due to the building shake, and when the

door opening time, if the swing amount of the rope,
which is estimated by the rope swing estimation module,
is a predetermined amount or more; and an operation
controller configured to control an operation of the
5 car, based on presence/absence of call registration
after door closing of the car and information of a
floor at which the car is at rest.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is an exemplary view illustrating the
10 structure of an elevator according to a first
embodiment.

FIG. 2 is an exemplary block diagram illustrating
the functional structure of a control apparatus of the
elevator in the first embodiment.

15 FIG. 3 is an exemplary graph illustrating a
relationship between a swing (maximum displacement) of
a car-side main rope of the elevator and a car position
in the first embodiment.

FIG. 4 is an exemplary graph illustrating a
20 relationship between a swing (maximum displacement) of
a counterweight-side main rope of the elevator and a
car position in the first embodiment.

FIG. 5 is an exemplary graph illustrating a
relationship between a swing (maximum displacement) of
25 a car-side compensating rope of the elevator and a car
position in the first embodiment.

FIG. 6 is an exemplary graph illustrating a

relationship between a swing (maximum displacement) of a counterweight-side compensating rope of the elevator and a car position in the first embodiment.

FIG. 7 is an exemplary flowchart illustrating a process operation of the control apparatus of the elevator in the first embodiment.

FIG. 8 is an exemplary flowchart illustrating a process relating to a door opening restriction of a control apparatus of an elevator in a second embodiment.

FIG. 9 is an exemplary block diagram illustrating the functional configuration of a control apparatus of an elevator in a third embodiment.

FIG. 10 is an exemplary flowchart illustrating a part of a process operation of the control apparatus of the elevator in the third embodiment.

FIG. 11 is an exemplary flowchart illustrating a process relating to a load restriction of a control apparatus of an elevator in a fourth embodiment.

DETAILED DESCRIPTION

Various embodiments will be described hereinafter with reference to the accompanying drawings.

(First Embodiment)

FIG. 1 shows the structure of an elevator according to a first embodiment. The case is now assumed that an elevator 11 is disposed in a building 10.

As shown in FIG. 1, a winder 12, which is a driving source of the elevator 11, is disposed in a machine room 10a at an uppermost part of the building 10. Incidentally, in a machine-room-less type elevator, the winder 12 is disposed at an upper part within an elevation shaft 10b. The machine-room-less type elevator is an elevator having no machine room.

A main rope 13 is wound around the winder 12. A car 14 is attached to one end portion of the main rope 13, and a counterweight 15 is attached to the other end portion of the main rope 13. In addition, a compensating sheave 16 is provided at a lowermost part of the elevation shaft 10b. Both end portions of a compensating rope 17 are attached via the compensating sheave 16 to a lower part of the car 14 and a lower part of the counterweight 15, respectively.

In addition, a car control device 18 is provided at an upper part of the car 14. When the car 14 arrives at any one of halls 21a, 21b, 21c, ..., of respective floors, the car control device 18 controls opening/closing of a car door 19. Incidentally, the car control device 18 is connected to a control apparatus 22 (to be described later) via a transmission cable 20 which is called "tail cord".

On the other hand, a control apparatus 22 for controlling the operation of the elevator 11 is disposed in the machine room 10a of the building 10 or

in the elevation shaft 10b in the case of the machine-room-less type.

The control apparatus 22 is composed of a computer in which a CPU, a ROM, a RAM, etc. are mounted. The control apparatus 22 executes a series of processes relating to the operation control of the elevator 11, such as driving control of the winder 12. Furthermore, the control apparatus 22 includes a function of estimating a swing of the rope due to a shake of the building 10 when the building 10 has been shaken by an earthquake, a strong wind, etc., and a function of controlling opening/closing of the door of the car 14, based on the result of the estimation.

The term "rope swing" refers to a swing of a rope in the horizontal direction, which is caused by a shake of the building 10. The "rope", in this context, refers to ropes relating to the elevation operation of the car 14, the ropes including the compensating rope 17, as well as the main rope 13, in the example shown in FIG. 1.

An acceleration sensor 23, which functions as a building shake detection module for detecting a shake of the building 10 due to an earthquake, a strong wind, etc., is disposed near the upper part of the building 10. The acceleration sensor 23 is composed of a two-axis acceleration sensor which can detect accelerations in the horizontal directions (x direction

and y direction) of a building, and outputs a detection signal thereof to the control apparatus 22.

FIG. 2 is a block diagram illustrating the functional structure of the control apparatus 22 of the elevator in the first embodiment.

As shown in FIG. 2, the control apparatus 22 includes a rope swing estimation module 31, an operation controller 32 and a notification module 33.

The rope swing estimation module 31 estimates a swing amount of the rope, based on the shake amount of the building 10, which is detected by the acceleration sensor 23, and the position of the car 14. The car position can be detected, for example, from a pulse signal which is output, in synchronism with the rotation of the winder 12, from a pulse generator (not shown) which is attached to a rotation shaft of the winder 12. The swing amount of the rope can be calculated by using a predetermined function expression. Since a concrete method of calculating the swing amount is publicly known, a detailed description of the method is omitted here.

The operation controller 32 controls the operation of the car 14, based on the presence/absence of call registration after door closing of the car 14 and information of a floor (an evacuation floor or not) at which the car 14 is at rest. In addition, the operation controller 32 includes a door opening

restriction module 32a. The door opening restriction module 32a executes an operation to restrict the door opening time of the car 14 to a time shorter than a normal time when the car 14 stops at each floor, if the
5 swing amount of the rope, which has been estimated by the rope swing estimation module 31, is a predetermined amount or more, which is set as a reference for determining the control operation.

The notification module 33 notifies passengers of
10 the quickening of door closing, when the door closing time of the car 14 has been restricted by the operation controller 32. A concrete example of the method of notification is a buzzing sound or a speech announcement. Incidentally, both the buzzing sound and
15 speech announcement may be used for the notification. In the present embodiment, the case in which notification is made by a buzzing sound is described by way of example.

In the car 14, destination floor buttons 41
20 corresponding to the respective floors, a door opening button 42a, a door closing button 42b and a buzzer 43 are provided. If a destination floor of a user is designated by the operation of the destination floor button 41, the designated destination floor is notified
25 to the control apparatus 22 as a car call. Upon receiving the car call, the control apparatus 22 moves the car 14 to the floor designated by the user.

The door opening button 42a is an operation button for the passenger to instruct door opening, and the door closing button 42b is an operation button for the passenger to instruct door closing. In addition, the
5 buzzer 43 is caused to make a buzzing sound by a driving signal from the notification module 33, when the car 14 has stopped at each floor.

Besides, the hall 21a, 21b, 21c, ..., of each floor is provided with hall call buttons (not shown). If a
10 hall call (destination direction) is registered by the operation of the hall call button, the hall call is sent to the control apparatus 22. Upon receiving the hall call, the control apparatus 22 moves the car 14 to the floor for which the hall call has been registered.

15 Next, the relationship between a rope swing and a car position is explained.

The "rope" refers to the main rope 13 and compensating rope 17. Specifically, the main rope 13 is divided into a main rope 13a which is attached to
20 the car 14, and a main rope 13b which is attached to the counterweight 15. The compensating rope 17 is divided into a compensating rope 17a which is attached to the car 14, and a compensating rope 17b which is attached to the counterweight 15.

25 The lengths of the ropes 13a, 13b, 17a and 17b vary depending on the position of the car 14. For example, paying attention to the main rope 13, when the

car 14 is at the lowermost floor, the main rope 13a on the car 14 side becomes longest. Conversely, the main rope 13b on the counterweight 15 side becomes shortest.

5 The rope swing estimation module 31, which is provided in the control apparatus 22, monitors the ropes 13a, 13b, 17a and 17b as monitor targets, and analyzes, by using a predetermined function expression, the relationship between the rope swing and the car position in relation to a building shake.

10 FIG. 3, FIG. 4, FIG. 5 and FIG. 6 show examples of results of analysis of the relationship between the rope swing and the car position, with respect to the ropes 13a, 13b, 17a and 17b.

15 FIG. 3 is a graph illustrating a relationship between a swing (maximum displacement) of the main rope 13a on the car 14 side and the car position. FIG. 4 is a graph illustrating a relationship between a swing (maximum displacement) of the main rope 13b on the counterweight 15 side and the car position.

20 The main rope 13a on the car 14 side has such characteristics that the main rope 13a swings to a maximum degree when the car 14 is near the lowermost floor. On the other hand, the main rope 13b on the counterweight 15 side has such characteristics that the
25 main rope 13b swings to a maximum degree when the car 14 is near the uppermost floor.

FIG. 5 is a graph illustrating a relationship

between a swing (maximum displacement) of the compensating rope 17a on the car 14 side and the car position. FIG. 6 is a graph illustrating a relationship between a swing (maximum displacement) of the compensating rope 17b on the counterweight 15 side and the car position.

The compensating rope 17a on the car 14 side has such characteristics that the compensating rope 17a swings to a maximum degree when the car 14 is at a floor slightly above a middle floor. On the other hand, the compensating rope 17b on the counterweight 15 side has such characteristics that the compensating rope 17b swings to a maximum degree when the car 14 is at a floor slightly below the middle floor.

FIG. 3 to FIG. 6 illustrate examples in the case where the building 10 shakes with a fixed shake amount. As the shake amount of the building 10 becomes greater, the swing amount of the rope 13a, 13b, 17a, 17b increases in proportion. In addition, the relationship between the rope swing and the car position varies depending on the characteristics of the building 10 and the characteristics of the elevator 11.

Since a concrete method of calculating the swing amount of the rope 13a, 13b, 17a, 17b from the shake amount of the building 10 is publicly known, a detailed description of the method is omitted here.

Next, the operation of the first embodiment is

described.

FIG. 7 is a flowchart illustrating a process operation of the control apparatus 22 of the elevator in the first embodiment.

5 If the building 10 shakes due to an earthquake or a strong wind, an acceleration signal corresponding to the shake amount of the building 10 is output from the acceleration sensor 23, which is disposed in the machine room 10a, to the control apparatus 22. If the
10 shake of the building 10 is detected (Yes in step S101), the rope swing estimation module 31, which is provided in the control apparatus 22, estimates the rope swing amount, based on the shake amount of the building 10, which is obtained from the acceleration
15 signal, and the present car position (step S102). Specifically, with respect to each of the ropes 13a, 13b, 17a and 17b, the rope swing estimation module 31 calculates the rope swing amount, relative to the shake amount of the building 10, by using a predetermined
20 function expression.

 The rope swing amount estimated by the rope swing estimation module 31 is delivered to the operation controller 32. If the swing amount of the rope is a predetermined amount or more (Yes in step S103), the
25 operation controller 32 determines at which floor the car 14 at rest, based on the operation information of the car 14 (step S104).

If the car 14 is at rest at a certain floor (Yes in step S104), the operation controller 32 then determines whether the door of the car 14 is open or not (step S105). The door open/closed state of the car
5 14 can be determined, based on a signal of a door switch (not shown) disposed on the car door 19. The operation controller 32 receives the signal of the door switch from the car control device 18, and determines whether the door of the car 14 is open or not.

10 If the door of the car 14 is open (Yes in step S105), the operation controller 32 executes a door opening restriction process by activating the door opening restriction module 32a, thereby to quicken door closing and to quickly move the car (step S106).

15 In the door opening restriction process, the door opening time (the time period in which the door is kept in the open state) of the car 14 is set to be shorter than a normal time. If the set time has passed, the door is forcibly closed. For example, if the normal
20 door opening time is T_{open} , the door opening time is decreased to about $4 \cdot T_{open}/5$ at the time of the door opening restriction. Specifically, if the the normal door opening time is $T_{open} = 10$ seconds, the door opening time is decreased to 8 seconds at the time of
25 the door opening restriction. After the passing of 8 seconds from the full opening of the car door 19, the door is forcibly closed.

At this time, the operation controller 32 causes, via the notification module 33, the buzzer 43 in the car 14 to make a buzzing sound, thereby notifying passengers of a "full-of-passengers" state and stopping
5 passengers from getting in the car 14 (step S107).

In usual cases, the car 14 is provided with the door opening button 42a. If the door opening button 42a is pressed (Yes in step S108), the operation controller 32 does not close the door even after the
10 passing of the door opening time, and keeps the door in the open state. This is for the purpose of safety, and the operation of the door opening button 42a is enabled in order to prevent a passenger from being caught in the door due to, for example, jumping-on. Similarly, a
15 door safety function (not shown) is also enabled. If the door opening button 42a is not pressed (No in step S108), the operation controller 32 closes the door of the car 14 via the car control device 18 (step S109).

In addition, if a call (car call/hall call) is
20 registered after the closing of the door (Yes in step S110), the operation controller 32 moves the car 14 in response to the call (step S111). On the other hand, if no call is registered (No in step S111), the operation controller 32 determines whether the car 14
25 is at rest at the evacuation floor (step S112).

The "evacuation floor" refers to a non-resonance floor. As illustrated in FIG. 3 to FIG. 6, the swing

of the rope varies depending on the position of the car 14.

For example, the main rope 13a on the car 14 side has such characteristics that the main rope 13a swings
5 to a maximum degree when the car 14 is near the lowermost floor. Accordingly, as regards the main rope 13a, a floor near the lowermost floor is the resonance floor. On the other hand, the main rope 13b on the counterweight 15 side has such characteristics that the
10 main rope 13b swings to a maximum degree when the car 14 is near the uppermost floor. Accordingly, as regards the main rope 13b, a floor near the uppermost floor is the resonance floor.

The same applies to the compensating rope 17a
15 which is attached to the car 14, and the compensating rope 17b which is attached to the counterweight 15. There are resonance floors at which the compensating rope 17a and the compensating rope 17b swing to maximum degrees, respectively, depending on the position of the
20 car 14.

Non-resonance floors can be found from the result of comprehensive analysis of the swing characteristics of the ropes 13a, 13b, 17a and 17b. In general, since the swing amount of the rope 13a, 13b, 17a, 17b is
25 small near the center of the building 10, a floor near the center is a non-resonance floor, and this floor is set as one of evacuation floors at which the car 14 is

safe even when the car 14 is at rest.

5 If the car 14 is at rest at the evacuation floor
(Yes in step S112), the operation controller 32 does
not move the car 14 after the door is closed, and
causes the car 14 to stand by until the rope swing
attenuates (step S113). On the other hand, if the car
14 is at rest at a floor other than the evacuation
floor (No in step S112), the operation controller 32
moves the car 14 to the evacuation floor immediately
10 after the door is closed (step S114). By moving the
car 14 to the evacuation floor, an increase of the rope
swing can be prevented, and the car 14 can be made to
safely stand by until the rope swing attenuates.

As has been described above, according to the
15 first embodiment, when the rope swings to a degree
greater than a predetermined amount, the door opening
time of the car 14 is shortened and the closing of the
door is quickened. Thereby, an increase of the rope
swing due to long-time standstill of the car 14 can be
20 prevented, the car 14 can be moved as early as possible
to the safe floor, and the operation service can be
continued.

(Second Embodiment)

Next, a second embodiment is described.

25 In the first embodiment, the time of the door
opening restriction is fixed regardless of the swing
amount of the rope. By contrast, in the second

embodiment, the time for the door opening restriction is stepwise varied in accordance with the swing amount of the rope.

5 In the meantime, since the basic structure of the control apparatus 22 is the same as that in the first embodiment, the process operation will be described below with reference to FIG. 8.

FIG. 8 is a flowchart illustrating a process relating to a door opening restriction of the control
10 apparatus 22 of the elevator in the second embodiment. The process illustrated in this flowchart is executed in step S106 in FIG. 7.

Specifically, in the case where the swing amount of the rope is a predetermined amount or more and the
15 car 14 is at rest with the door opened at this time, the operation controller 32 provided in the control apparatus 22 executes the door opening restriction process by activating the door opening restriction module 32a, thereby to quicken door closing and to
20 quickly move the car (step S106).

As illustrated in FIG. 8, in this door opening restriction process, the operation controller 32 estimates a future condition, from a variation of the swing amount of the rope, which is successively
25 obtained with the passing of time by the rope swing estimation module 31 (step S201).

As a result, if the rope swing is in a state of

increasing when the car 14 stops and opens the door
(Yes in step S202), the operation controller 32
stepwise shortens the door opening time (the time
period in which the door is kept in the open state) in
5 accordance with the swing amount of the rope at this
time (step S203).

For example, assuming that the swing amount of the
rope, which has been estimated by the rope swing
estimation module 31, is d , and the normal door opening
10 time is T_{open} , the door opening time is stepwise set as
follows:

When $D1 \leq d < D2$: $4 \cdot T_{open}/5$,

When $D2 \leq d < D3$: $3 \cdot T_{open}/5$, and

When $D3 \leq d$: $2 \cdot T_{open}/5$.

15 $D1$, $D2$ and $D3$ are thresholds for the rope swing
amount, and $D1 < D2 < D3$. For example, if T_{open} at
normal time is 10 seconds, at the time of the door
opening restriction, as the rope swing amount
increases, the door opening time is stepwise shortened,
20 for example, in such a manner as 8 seconds $\rightarrow$
6 seconds $\rightarrow$ 4 seconds.

The subsequent process is the same as in the first
embodiment. The operation controller 32 causes, via
the notification module 33, the buzzer 43 in the car 14
25 to make a buzzing sound, thereby notifying passengers
of the quickening of door closing. In addition, after
the door is closed, if a call is registered, the call

is responded to. If there is no call registered, the operation of the car 14 is controlled so that the car 14 stands by at the evacuation floor.

On the other hand, if the rope swing is in a state
5 of attenuating when the car 14 stops and opens the door (No in step S202), the operation controller 32 closes the door after the passing of the normal door opening time, without executing the door opening restriction (step S204). In this case, the quickening of door
10 closing is not notified. In addition, the car 14 is not forcibly moved to the evacuation floor.

As has been described above, according to the second embodiment, when the rope swing is in a state of increasing, the time for door opening restriction is
15 stepwise varied in accordance with the swing amount of the rope at this time. Thus, as the swing of the rope is greater, it is possible to avoid the dangerous state by closing the door earlier. On the other hand, when the rope swing is in a state of attenuating, the door
20 opening restriction is canceled. Thereby, inconvenience to passengers, which is caused by frequent shortening of the door opening time, can be prevented.

(Third Embodiment)

25 Next, a third embodiment is described.

In the third embodiment, door closing is quickened by executing a load restriction, in addition to the

door closing restriction described in the first and second embodiments.

FIG. 9 is a block diagram illustrating the functional configuration of a control apparatus 22 of an elevator in the third embodiment. The same components as those in FIG. 2 in the first embodiment are denoted by like reference numerals, and a description thereof is omitted.

In the third embodiment, the operation controller 32 of the control apparatus 22 is provided with a load restriction module 32b, in addition to the door closing restriction module 32a. The load restriction module 32b restricts the upper limit value of the load of the car 14.

Specifically, the upper limit value of the load (rated load) of the car 14 is preset. If passengers exceeding the upper limit value get on the car 14, a "full-of-passengers" lamp is turned on and the buzzer makes a buzzing sound. A load sensor 44 functioning as a load detection module is disposed at the bottom of the car 14. The load sensor 44 detects the load which varies due to getting on/off of passengers.

Information about the load that is detected by the load sensor 44 is sent to the control apparatus 22 via the car control device 18.

In this structure, the flow of the basic process is the same as in the flowchart of FIG. 7 which has

been described in connection with the first embodiment,
so only different parts are described below.

FIG. 10 is an exemplary flowchart illustrating a
part of a process operation of the control apparatus 22
5 of the elevator in the third embodiment. In this
flowchart, step S300 is added after step S106 in
FIG. 7.

Specifically, if the swing amount of the rope is
the predetermined amount or more and the car 14 is at
10 rest with the door opened at this time, the operation
controller 32 provided in the control apparatus 22
executes the door opening restriction process by
activating the door opening restriction module 32a,
thereby to quicken door closing and to quickly move the
15 car (step S106). Specifically, as described in
connection with the first embodiment, the door opening
time (the time period in which the door is kept in the
open state) of the car 14 is set to be shorter than a
normal time, and the door is forcibly closed after the
20 passing of the set time. In the meantime, by applying
the method of the above-described second embodiment,
the time for the door opening restriction may be
stepwise varied in accordance with the swing amount of
the rope.

25 Following the above-described door opening
restriction process, the operation controller 32
executes the load restriction process by activating the

load restriction module 32b (step S300). In the load restriction process, the upper limit value of the load of the car 14 is set to be lower than a normal value.

For example, if the upper limit value (rated load) of the normal load is G_{max} , the upper limit value at the time of load restriction is set to be as low as about $4 \cdot G_{max}/5$. Specifically, if the upper limit value G_{max} at the normal time is 1000 kg, the upper limit value G_{max} at the time of load restriction is 800 kg.

The operation controller 32 detects the present load by the load sensor 44 which is disposed at the bottom of the car 14. If the detected load has exceeded the upper limit value which has been set by the above-described load restriction process, the operation controller 32 causes, via the notification module 33, the buzzer 43 in the car 14 to make a buzzing sound, thereby notifying passengers of a "full-of-passengers" state and stopping passengers from getting in the car 14 (step S107).

In the meantime, if the door opening time that was set by the above-described door opening restriction process has passed before the load exceeds the upper limit value, the buzzer 43 produces a buzzing sound. In short, the buzzer 43 makes a buzzing sound on the condition of either the door opening restriction or the load restriction.

The subsequent process is the same as in the first embodiment. After the door of the car 14 is closed, if a call is registered, the call is responded to. If there is no call registered, the operation of the car 14 is controlled so that the car 14 stands by at the evacuation floor.

As has been described above, according to the third embodiment, the load restriction is executed when the rope is swinging by the predetermined amount or more, and hence the number of passengers can be decreased and the door closing can be quickened. Thereby, an increase of the rope swing due to long-time standstill of the car 14 can be prevented, the car 14 can be moved as early as possible to the safe floor, and the operation service can be continued.

(Fourth Embodiment)

Next, a fourth embodiment is described.

In the third embodiment, the upper limit value of the load restriction is fixed regardless of the swing amount of the rope. By contrast, in the fourth embodiment, the upper limit value of the load restriction is stepwise varied in accordance with the swing amount of the rope.

In the meantime, since the basic structure of the control apparatus 22 is the same as that in the first embodiment, the process operation will be described below with reference to FIG. 11.

FIG. 11 is an exemplary flowchart illustrating a process relating to the load restriction of the control apparatus 22 of an elevator in the fourth embodiment. The process illustrated in this flowchart is executed
5 in step S300 in FIG. 10.

Specifically, in the case where the swing amount of the rope is the predetermined amount or more and the car 14 is at rest with the door opened at this time, the operation controller 32 provided in the control
10 apparatus 22 executes the load restriction process by activating the load restriction module 32b, thereby to quicken door closing and to quickly move the car (step S300).

As illustrated in FIG. 11, in this load
15 restriction process, the operation controller 32 estimates a future condition, from a variation of the swing amount of the rope, which is successively obtained with the passing of time by the rope swing estimation module 31 (step S301).

20 As a result, if the rope swing is in a state of increasing when the car 14 stops and opens the door (Yes in step S302), the operation controller 32 stepwise decreases the upper limit value of the load of the car 14 in accordance with the swing amount of the
25 rope at this time (step S303).

For example, assuming that the swing amount of the rope, which has been estimated by the rope swing

estimation module 31, is d , and the normal upper limit value (rated load) of the load is $G_{\max}$, the upper limit value of the load is stepwise set as follows:

When $D1 \leq d < D2$: $4 \cdot G_{\max}/5$,

5 When $D2 \leq d < D3$: $3 \cdot G_{\max}/5$, and

When $D3 \leq d$: $2 \cdot G_{\max}/5$.

$D1$, $D2$ and $D3$ are thresholds for the rope swing amount, and $D1 < D2 < D3$. For example, if $G_{\max}$ at normal time is 1000 kg, at the time of the load
10 restriction, as the rope swing amount increases, the upper limit value of the load is stepwise decreased, for example, in such a manner as 800 kg $\rightarrow$ 600 kg $\rightarrow$ 400 kg.

The subsequent process is the same as in the first
15 embodiment. The operation controller 32 causes, via the notification module 33, the buzzer 43 in the car 14 to make a buzzing sound, thereby notifying passengers of the quickening of door closing. In addition, after the door is closed, if a call is registered, the call
20 is responded to. If there is no call registered, the operation of the car 14 is controlled so that the car 14 stands by at the evacuation floor.

On the other hand, if the rope swing is in a state of attenuating when the car 14 stops and opens the door
25 (No in step S202), the operation controller 32 monitors the load by using the normal upper limit value, without executing the load restriction, and makes notification

if the upper limit value is exceeded (step S304). In this case, the car 14 is not forcibly moved to the evacuation floor.

As has been described above, according to the
5 fourth embodiment, when the rope swing is in a state of increasing, the upper limit value of the load is stepwise varied in accordance with the swing amount of the rope at this time. Thus, as the swing of the rope is greater, it is possible to avoid the dangerous state
10 by decreasing the number of passengers and closing the door earlier. On the other hand, when the rope swing is in a state of attenuating, the load restriction is canceled. Thereby, inconvenience to passengers, which is caused by frequent lowering of the upper limit value
15 of the load, can be prevented.

In each of the above-described embodiments, the door closing is quickened at no matter which floor the car 14 is at rest, regardless of the car position. However, when the car 14 is at rest at the evacuation
20 floor at which the rope swing is small, the normal door closing operation may be performed without quickening door closing. In this case, for example, in the flowchart of FIG. 7, a process of determining whether the floor, at which the car door is in the open state, is the evacuation floor or not, is added after "Yes" of
25 step S105. If the floor, at which the door is in the open state, is the evacuation floor, the door opening

restriction is not executed and the process advances to
step S109, thereby closing the door as usual. If the
floor, at which the door is in the open state, is a
floor other than the evacuation floor, the process may
5 advance to step S106, thereby executing the door
opening restriction.

According to at least one of the above-described
embodiments, there can be provided a control apparatus
of an elevator, which can ensure safety and continue an
10 operation service when a building has shaken, without
transitioning to a control operation as much as
possible.

While certain embodiments have been described,
these embodiments have been presented by way of example
15 only, and are not intended to limit the scope of the
inventions. Indeed, the novel embodiments described
herein may be embodied in a variety of other forms;
furthermore, various omissions, substitutions and
changes in the form of the embodiments described herein
20 may be made without departing from the spirit of the
inventions. The accompanying claims and their
equivalents are intended to cover such forms or
modifications as would fall within the scope and spirit
of the inventions.

WHAT IS CLAIMED IS:

1. A control apparatus of an elevator including a car which elevates via a rope disposed in an elevation shaft in a building, comprising:

5 a building shake detection module configured to detect a shake of the building;

 a rope swing estimation module configured to estimate a swing amount of the rope, based on a building shake amount detected by the building shake
10 detection module and a position of the car;

 a door opening restriction module configured to restrict a door opening time at a time when the car stops at each of floors to a time shorter than a normal door opening time, if the swing amount of the rope,
15 which is estimated by the rope swing estimation module, is a predetermined amount or more; and

 an operation controller configured to control an operation of the car, based on presence/absence of call registration after door closing of the car and
20 information of a floor at which the car is at rest.

2. The control apparatus of the elevator of Claim 1, wherein the door opening restriction module is configured to stepwise shorten the door opening time of the car in accordance with the swing amount of the rope at a time when it has been determined, from a variation
25 of the swing amount of the rope estimated by the rope swing estimation module, that the rope swing is in a

state of increasing.

3. The control apparatus of the elevator of
Claim 1, wherein the door opening restriction module is
configured not to restrict the door opening time of the
5 car, when it has been determined, from a variation of
the swing amount of the rope estimated by the rope
swing estimation module, that the rope swing is in a
state of attenuating.

4. The control apparatus of the elevator of
10 Claim 1 or Claim 2, further comprising a notification
module configured to notify passengers of quickening of
door closing, when the door opening time of the car has
been restricted by the door opening restriction module.

5. The control apparatus of the elevator of
15 Claim 1, further comprising a load restriction module
configured to restrict an upper limit value of a load
of the car to a value lower than a normal value, when
the swing amount of the rope, which is estimated by the
rope swing estimation module, is the predetermined
20 amount or more.

6. The control apparatus of the elevator of
Claim 5, wherein the load restriction module is
configured to stepwise lower the upper limit value of
the load of the car in accordance with the swing amount
25 of the rope at a time when it has been determined, from
a variation of the swing amount of the rope estimated
by the rope swing estimation module, that the rope

swing is in a state of increasing.

7. The control apparatus of the elevator of Claim 5, wherein the load restriction module is configured not to restrict the upper limit value of the load of the car, when it has been determined, from a variation of the swing amount of the rope estimated by the rope swing estimation module, that the rope swing is in a state of attenuating.

8. The control apparatus of the elevator of Claim 5 or Claim 6, further comprising a notification module configured to notify passengers of quickening of door closing, when the upper limit value of the load of the car has been restricted by the load restriction module.

9. The control apparatus of the elevator of Claim 1, wherein the operation controller is configured to cause the car to stand by at a predetermined evacuation floor, if there is no call registration after the door closing of the car and the car is at rest at the predetermined evacuation floor.

10. The control apparatus of the elevator of Claim 1, wherein the operation controller is configured to forcibly move the car to a predetermined evacuation floor, if there is no call registration after the door closing of the car and the car is at rest at a floor other than the predetermined evacuation floor.