

ELEVATOR

BACKGROUND OF THE INVENTION

The present invention relates to elevators which are moved up and down along guide rails and more particularly, to an elevator which can have a good riding comfort by suppressing the vibration of an elevator car.

5 In an elevator, an elevator car is suspended by a rope and is moved up or down by winding or rewinding the rope. The elevator car is moved up or down along guide rails provided at right and left sides of an elevator move up/down passage via shoes provided at upper and lower sides of the elevator car or via a guide device using guide rollers.

In order to reduce the vibration or tilt of an elevator car, it is known to control
10 pushing pressures of two guide rollers against a guide rail provided at both sides of the guide rail, which is disclosed, for example, in JP-A-2006-131385.

In order to actively attenuate vibration by forcibly applying an external force to an elevator car in such a direction as to cancel vibration generated from a guide rail and so on, it is also known to provide an acceleration sensor for detecting the acceleration of an elevator car and
15 a controller at at least one of upper and lower parts of the elevator car, which is disclosed, for example, in JP-A-6-72667.

Further, it is known to perform cooperative control over an elevator car by providing a total of four actuators at upper, lower, right and left sides of the elevator car, and more specifically to optimize the elevator car by changing parameters of a multivariable
20 regulator until finding of a minimum value by an H-infinity control method, which is disclose, for example, in JP-A-2005-219929.

SUMMARY OF THE INVENTION

The vibration of an elevator car during its running operation has not only a translational vibration mode but also a plurality of vibration modes including a rotational
25 vibration mode. Thus, it is difficult in JP-A-2006-131385 and JP-A-6-72667 to suppress the plurality of vibration modes.

Since it is required to optimize a function having a multiplicity of variables in JP-A-2005-219929, it is required to complicate a controller and to provide an increased number of actuators, which is impractical.

30 An object of the present invention is to solve the above problems in the prior art

and to simplify a controller, enhance a vibration suppressing effect with use of a less number of actuators, and facilitate installation and adjustment.

Another object of the present invention is, in addition to the above, to reduce the height dimension of an elevator car.

5 The above objects of the present invention can be attained by providing an elevator which includes guide rails provided vertically within an elevator move up/down passage, an elevator car which is moved up or down along the guide rails, and an acceleration sensor for detecting the acceleration of the elevator car, and actuators driven to cancel the vibration of the elevator car according to a signal detected by the acceleration sensor, wherein
10 the elevator further including guide devices provided at the upper and lower parts of the elevator car to push guide rollers against the guide rails via springs, and at least one of the guide devices provided at the upper and lower parts of the elevator car has a rigidity not smaller than 2 times of a rigidity of the other guide device and not larger than 5 times thereof.

 In accordance with the present invention, at least one of the guide devices
15 provided at the upper and lower parts of the elevator car is set to have a rigidity equal to or larger than 2 times of a rigidity of the other guide device and equal to or smaller than 5 times thereof. As a result, when application of forced displacement vibration to the rails causes excitation of two vibration modes of translation and rotation (pitching) of the elevator car, an response acceleration at a position of a floor as an evaluation surface is an overlap of time responses of the
20 respective vibration modes, and therefore a difference (time lag) in phase between the response accelerations of the modes can be made small. Accordingly, when the phase difference to responses of the translational and rotational modes can be made small, the controller can be simplified and a vibration suppressing effect can be enhanced with a less number of actuators.

BRIEF DESCRIPTION OF THE DRAWINGS

25 FIG. 1 shows a perspective view of an elevator according to an embodiment of the present invention;

 FIG. 2 is a side view of a guide device in the embodiment;

 FIG. 3 is a cross-sectional view of a side of the guide device in the embodiment;

 FIG. 4 shows, in a model form, vibration modes of a elevator car in the
30 embodiment;

 FIG. 5 is a graph showing a vibration phase difference in the embodiment;

 FIG. 6 is a block diagram of a control system in the embodiment; and

 FIG. 7 shows graphs explaining a vibration suppressing effect in the embodiment.

DESCRIPTION OF THE EMBODIMENTS

Explanation will be made as to an embodiment of the present invention with use of the accompanying drawings.

The vibration of an elevator during its running operation includes vertical and
5 horizontal vibrations. The vertical vibration is generated when a torque ripple of a motor of a hoist or focibly applied vibration of a sheave or a pulley caused by its eccentricity is propagated to a rope. For this reason, it is required to reduce the ripple of the motor and the eccentricity of rotating members.

The horizontal vibration is generated mainly when a forced displacement caused
10 by a bent or a step in the guide rail is applied to the elevator car. In a high-speed elevator, a vibration application frequency caused by the bent is increased. In order to reduce the horizontal vibration, elevator installation is managed so that the installation error of the guide rails becomes small or an isolation rubber or a damper is provided at the lower side of the guide device or elevator car to attenuate the vibration.

15 In order to effectively suppress two vibration modes mainly including translational and rotational movements as the vibration (elevator car swing) of the elevator car during its running operation, it is desirable to reduce phase differences between inputs (forced displacement waveforms) of the excited 2 vibration modes to the response of the floor surface as the evaluation position. This can be attained only by changing a gravity position or the rigidity
20 of the guide device which greatly influences the dynamic characteristic of the elevator car. However, change of the gravity position is only required to mount, for example, a weight on the upper or lower side of the elevator car, which results in an increase in the mass of the elevator car, thus increasing the number of ropes. This can also be attained by changing the placement of heavy-weighted devices, but this is practically difficult due to dimensional restrictions.

25 Further, even if the design value of the rigidity of the guide device is determined, the design value of the guide device actually installed in the field dose not coincide necessarily with its design value. For this reason, it is good that the rigidity of the guide device can be easily changed in the field.

FIG. 1 shows a perspective view of an elevator car 1 of an elevator. In the
30 following description, it is assumed that a depth direction of a front of the elevator car 1 is an X direction, a horizontal direction thereof is a Y direction, and a vertical direction thereof is a Z direction.

In the elevator, the elevator car 1 is connected to a balancing weight via a rope 3 and these are driven by a hoist (not shown). The rope 3 is provided at the upper part of the

elevator car 1 nearly in its center. A pair of right and left guide rails 2a, 2b having a T-shaped cross section are provided vertically within a move up/down passage of the elevator and the elevator car 1 is vertically moved up or down along guide rails 2a, 2b. Though not shown, various devices including a door driving device, a rope end, guide devices and an emergency stop device are provided at the upper and lower part of the elevator car 1.

Since the guide rails 2a, 2b have each a length of 4-5m and have each guide rail members and each guide rail is installed in a vertical direction by connecting the guide rail members each other; steps or bents are generated at the connection points. These steps and bents act on the elevator car 1 as a forced displacement. Guide devices for guiding the elevator car in move up/down directions are provided at for 4 locations of the upper and lower parts of the elevator car to hold the guide rails 2a, 2b having the T-shaped section therebetween, because the guide devices prevent propagation of vibration caused by the forced displacement to the elevator car 1.

The guide device has levers which support guide rollers through their shafts in their center and also are rotated at their fixed pivots and has springs for pushing the guide rollers against the rails. The rigidity of the guide rail indicates a contact stiffness between the elevator car and the guide rail at a central position of the guide rail contacted with the guide rail. For this reason, the rigidity of the guide device can be increased by increasing the rigidity of the rubber of the guide rail, by increasing the constant of the spring, and by increasing a lever ratio of a distance from the pivot to a spring position to a distance from the pivot to the center of the guide roller, that is, a leverage ratio. Since the rigidity of the guide roller rubber is sufficiently higher than that of the spring (10 times or more), the rigidity (equivalent spring constant: spring constant converted to the central position of the guide roller) of the guide device is determined by the spring constant of the spring and the leverage ratio of the lever.

In order to suppress vibration propagation, the guide roller is made of a rubber and is connected to the elevator car 1 via the spring. The lever connected to the guide roller through the shaft is provided with a damper. In order to reduce the vibration of the elevator car 1, the rigidity of the guide device can be made smaller to reduce a vibration transmissibility. However, since this causes the tilt of the elevator car 1 to become large when a passenger or passengers get into the elevator, the rigidity of the guide device is set to have a value not smaller than a constant value.

In FIG. 1, guide devices having vibration suppressing actuators are provided on the lower part of the elevator car 1 at right and left sides. An actuator 21a is connected to a spring 12a for pushing a guide roller 11a against a guide rail 2b. Such an actuator is also

disposed even at the left side in the X direction and at the right side in the Y direction, and these actuators are connected to the associated springs.

The elevator car 1 is provided with acceleration sensors 20a, 20b for detecting vibration. The acceleration sensors detect accelerations in two directions, that is, an anterior-posterior direction and a transverse direction. Actuators 21a, 21b, 21c perform feedback control in response to signals detected by the acceleration sensors 20a, 20b and are driven so as to cancel the vibration of the elevator car 1. The acceleration sensors 20a, 20b are provided at the lower side of the elevator car 1. However, the acceleration sensors are not limited to the above installation positions but may be provided at only the upper side of the elevator car or at both of the upper and lower sides thereof. In order to detect a rotational movement around the Y axis of the car, in this case, the acceleration sensors are provided at different positions in the car height direction.

The elevator car 1 has vibration generated by bents of the rails and so on, but the vibration has a plurality of vibration modes including not only a translational movement only in the X direction but also a combination of translational and rotational movements. Though such movements are generally called rolling, pitching or yawing, front and advancing directions in the elevator are different from those in vehicles and ships, and thus such movements will be referred to as X-axis rotation, Y-axis rotation and Z-axis rotation modes, hereinafter.

FIG. 2 shows a guide device for performing vibration control in the X direction in FIG. 1. Two guide rollers 9a, 9b are arranged so as to hold a rail (not shown) therebetween from right and left sides. The guide rollers 9a, 9b are connected at their central parts to levers 36a, 36b by bolts 61a, 61b. The levers 36a, 36b are fixed by bases 33a, 33b and bolts 32a, 32b, and the bases 33a, 33b are fixed to the lower side of the elevator car 1. Springs 12a, 12b for pushing the guide rollers 9a, 9b against the rail are coil springs and are positioned at positions lower than the centers of the guide rollers.

A movable member 40 is fixed to the levers 36a, 36b via rods 45a, 45b so that pushing amounts of the springs 12a, 12b can be adjusted. The actuator 21a has a motor 41 and a ball screw 42, and is connected to the movable member 40. The movable member 40 has a linear guide 39 for restricting a movement in the vertical direction and thus can be moved only in the horizontal direction.

In order to reduce a height h of the entire guide device, pivots 32a, 32b of the levers 36a, 36b are located close to the centers of the guide rollers 9a, 9b so that their projection cross sections are overlapped in the vertical direction of the paper sheet. The guide rollers 9a, 9b are provided therein with holes 34a, 34b in a circumferential direction, and the bolts 32a, 32b

are provided in the holes in pitch circumferential lines 35a, 35b. With this arrangement, the height h is reduced by stacking the guide rollers 9a, 9b, the levers 36a, 36b and the bases 33a, 33b in the height direction without being interfered in the vertical direction of the paper sheet.

FIG. 3 is a side cross sectional view of the guide rollers 9a, 9b, the levers 36a, 36b and the bases 33a, 33b located in the X direction. The guide roller 9b, the lever 36b and the base 33b are located without all being overlapped each other. When the fixing bolt 32b is inserted from the left side and then passed through the hole 34b provided in the guide roller 9b, the lever 36b can be connected to the base 33b.

The smaller a distance b from the center of the guide roller to the pivot of the lever is and the larger a distance a from the center of the guide roller to the spring position is, the larger the rigidity of the guide device. When the positions of the springs 12a, 12b are changed to positions 38a, 38b shown by dotted lines, the rigidity (equivalent spring constant) of the guide device can be changed. Since a large leverage ratio of the lever based on a spring position from the pivot to the center of the guide roller can be secured by moving the lever pivot close from the center of the guide roller, a change in the rigidity caused by a change (from a to a') of the spring position can be made similarly large.

As a result, when it is desired to change the rigidity of the guide device in an installation site, adjusting works can be easily conducted without any need of preparing a plurality of springs having different spring constants. In order to change of positions of the springs 12a, 12b in the height direction, each of the levers 36a, 36b is provided therein with a groove 48 (see FIG. 3), so that the positions of the springs 12a, 12b can be slidably changed. Although the dimension a can be changed by providing a plurality of holes (not shown) for fixing the rods 45a, 45b to the movable member 40 in the illustrated drawing, a spacer 46 may be provided between a supporting pole 31 and a base 44 to adjust the spring positions.

Explanation will next be made as to vibration modes in a XZ plane of the elevator of FIG. 1, with use of models in FIG. 4. FIG. 4 shows movements of an elevator car when the actuator 21a is provided at the lower side of the car and applies vibration to the car.

Models (a) and (b) in FIG. 4 show cases when translational and rotational modes vibrate in the same direction at a floor position 53 (when a phase difference of response displacement waveforms of the two modes to an input displacement waveform is zero as a most extreme case); and models (c) and (d) show cases when the translational and rotational modes are directed in opposed directions (when a phase difference of response displacement waveforms of the two modes to an input displacement waveform is 180 degrees as a most extreme case). In either case, most understandable condition states are used. Models in upper and lower stages

of the drawing and at most right sides indicate vibration states when the two vibration modes are overlapped.

An initial state of the elevator car is shown by dotted lines and the vibrating state of the car is shown by solid lines. In the translational mode of the upper stage model (a), the
5 elevator car is moved to the left side. Thus in order to suppress the movement, it is necessary to apply a control force to the right side of the actuator 21a. With use of the control force, the rotational mode of the model (b) can be similarly suppressed.

In the lower-stage models (c) and (d), on the other hand, when it is desired to suppress the translational mode in the model (c), the control force is applied to the right side of
10 the elevator car as in the case of the model (a). The control force is applied not to such a direction as to suppress the rotational mode of the model (d) but to such a side of the car as to increase the rotation of the car. Thus, with regard to the 2 modes shown in the upper-stage models (a) and (b), when an actuator is provided only at the lower side of the elevator car, an enhancement in the vibration suppressing effect is expected with use of such a structure design
15 that a phase difference to an input in each model is made small (the phase difference is made ideally zero with the states of the upper-stage models (a) and (b)).

FIG. 5 shows a computation result relating to phase differences of such 2 modes of translation (TX) and rotation (RY) in the XZ plane of the elevator car. An abscissa axis denotes a rigidity ratio obtained by dividing the rigidity of the upper-side guide device by the
20 rigidity of the lower-side guide device. The rigidity of the guide device is an equivalent spring constant (N/mm) converted to the central position of the guide roller, and is substantially determined by the spring constant of the spring and the leverage ratio of the lever.

FIG. 5 shows a computation result of phase differences of the 2 modes on the basis of the phase of a transfer function from a forced displacement to a floor surface
25 acceleration underwent by the upper- and lower-side guide devices. The transfer function is based on a two-degrees-of-freedom dynamics model having translation and rotation with a rigidity model one point mass. First, when the upper- and lower-side guide devices are denoted respectively by an initial rigidity k_0 and have the same k_0 value (a ratio of rigidities of the upper and lower guide devices being a relationship of 1 to 1), the upper and lower guide devices are
30 defined as initial structures. On the other hand, the structures of the upper and lower guide devices are changed to have rigidities of 'a' and 'b' times of k_0 respectively. FIG. 5 shows a computation result of phase differences of the two vibration modes when $a=1$ and $b=2$ are set. In this case, when a rigidity ratio is defined as a/b , this means that the larger the ratio a/b is, the rigidity of the upper guide device is larger than the rigidity of the other guide device, and that the

smaller the ratio a/b is, the rigidity of the lower guide device is larger than the rigidity of the other guide device.

In the case of the elevator, since the upper and lower guide devices pass on the same rail surface, the same forced displacement input acts on the elevator car. Between inputs
5 of the upper and lower guide devices, there is a time difference caused by a speed, an installation interval between the upper and lower guides and the rail length. For this reason, as illustrated in the drawing, phase differences of the 2 vibration modes are not the same and have different tendencies in the moving-up and -down operations of the elevator.

In this drawing, the rigidity ratio ($=a/b$) varies in range of 0.2 to 0.5 and the phase
10 differences are small in the range in both of the elevator move-up and -down operations. though not shown, the graph is not limited to when $b=2$, but even when $a=0.5$ and $b=1$ or when $a=1$ and $b=3$ as other conditions, nearly the same graph can be obtained.

In an actual elevator, when $b=5$ or a higher value, the guide device of the guide
15 device becomes too hard and this becomes too sensitive to rail misalignment, which is not practical from the viewpoint of reducing the vibration of the elevator car 1.

Accordingly, the rigidity ratio ($=a/b$) is in a range of 0.2 to 0.7 and more desirably
0.2 to 0.5; and it is good as corresponding design ranges that the lower side guide device is set have a rigidity in a range not smaller than 1.5 times of the rigidity of the upper side guide device and not larger than 5 times thereof, and more desirably not smaller than 2 times thereof and not
20 larger than 5 times thereof.

FIG. 6 is a block diagram of a feedback control system, showing a control system of 2 actuators 21a, 21b for suppressing vibrations of X-direction translation, rotation around the Y axis and rotation around the Z axis.

Signals of the acceleration sensors 20a, 20b provided at the lower side of the
25 elevator car are passed through low-pass filters 62a, 62b to remove noise therefrom. The signals are then inputted each parallelly to controllers 63a, 63b, 63c, 63d, so that a control command 65a for the actuator (21a in FIG. 1) is a sum of outputs from the controllers 63a, 63c, a control command 65b for the actuator (21b in FIG. 1) is a sum of outputs from the controllers 63b, 63d. In order to prevent excess currents to the actuators, limiters 64a, 64b are provided
30 respectively.

The controller may be designed with use of the H infinity control theory as one technique for a robust control design or the like for suppressing the uncertainty influence of a model by handling an uncertainty part of a control target as an external disturbance signal, so as to perform frequency shaping using a weight function considering human body riding comfort

sensitivity and so on. The controllers 63a, 63b, 63c, 63d may be designed based on the above control design or may be made up of a proportional control/phase compensation device which allows on-the-spot adjustment.

FIG. 7 shows simulation results of vibration suppressing effects of the initial structure and a structure having phase differences of two modes reduced when compared with the initial structure. A stepwise forced displacement simulating steps of the elevator car is applied to upper- and lower-side guides with different timings, and the then acceleration of the floor position is shown. When control is made even in an initial structure case (b), a vibration reduction of about 40% is recognized when compared with a no control case (a). In accordance with the present embodiment, on the other hand, the vibration suppressing effect is made high and a vibration suppressing effect of about 70% is recognized when compared with the no control case.

The above explanation has been made in connection with an arrangement wherein the gravity center position 54 of the elevator car 1 is located at a position lower than the centroid of the height direction and the actuator 21a is provided only at the lower side of the car. However, when the gravity center position 54 of the elevator car 1 is located at a position higher than the centroid, a similar vibration suppressing effect can be obtained by providing the actuator 21a at the upper side of the car and by setting the rigidity of the upper-side guide device to be higher than the rigidity of the lower-side guide device.

As has been explained above, in accordance with the above embodiment, a plurality of excited vibration modes are generated in the same direction to a rail misalignment. Further, with respect to a vibration transmission gain from the rail, since a vibration transmission gain from the lower-side guide device is larger than a vibration transmission gain of the upper-side guide device, the actuator is located at the lower side of the elevator car so that phase differences of 2 vibration modes of car translation and rotation (pitching) to inputs from the lower side become small at the floor position (equivalent to the actuator installation side).

More in detail, the rigidities of the guide devices located at the upper and lower sides are made not the same but different or asymmetrical, that is, the rigidity of the lower side guide device is higher than the rigidity of the upper side guide device. Further, the rigidity of the guide device is made high even by reducing a distance between the pivot of the lever for supporting the roller through the shaft and the center of the roller, locating the spring fixing part of the lever away from the roller center, and using the same springs. That is, this is equivalent to enlargement of a leverage ratio between the distance from the pivot to the roller center and the distance from the pivot to the spring position.

In addition, in order to making the roller close to the pivot position of the lever, the pivot of the lever is located within the projection section plane of the roller. The fixing bolts of the pivots are provided above the holes made in the roller along a pitch circle to be spaced by an equal spacing, and the lever is easily connected to the base of the guide device via
5 the bolts passed through the holes. Further, since the spring position of the roller can be vertically changed by providing a groove in the lever and by moving the spring vertically, the rigidity of the guide device can be easily changed on the spot without exchanging the spring, and a time required for installation and adjustment can be reduced. Since a distance between the center of the guide roller and the base of the guide device can be reduced, the height of the
10 elevator car can be reduced.

CLAIMS:

1. An elevator comprising guide rails (2a, 2b) provided in a vertical direction within an elevator move-up/down passage elevator move up/down passage, a elevator car (1) moved up or down along the guide rails, acceleration sensors (20a, 20b) for detecting an acceleration of the elevator car, and actuators (21a, 21b, 21c) driven so as to cancel vibration of the elevator car according to signals detected by the acceleration sensors,

wherein guide devices are provided at upper and lower sides of the elevator car to push guide rollers (9a, 9b) against the guide rails via springs (12a, 12b), a rigidity of at least one of the guide devices provided at the upper and lower sides of the elevator car is equal to or larger than 2 times of a rigidity of the other guide device and equal to or smaller than 5 times thereof.

2. The elevator according to claim 1, wherein the rigidity of the guide device provided at the lower side of the elevator car (1) is equal to or larger than 2 times of the rigidity of the guide device provided at the upper side of the car and equal to or smaller than 5 times thereof, and the actuators (21a, 21b, 21c) are provided at the lower side of the elevator car.

3. The elevator according to claim 1, wherein a rigidity of the guide device provided at the upper side of the elevator car (1) is equal to or larger than 2 times of a rigidity of the guide device provided at the lower side thereof and equal to or smaller than 5 times thereof, and the actuators (21a, 21b, 21c) are provided at the upper side of the elevator car.

4. The elevator according to claim 1, wherein the guide device includes levers (36a, 36b) for supporting the guide rollers (2a, 2b) through shafts at their centers to be rotated at fixed pivots and springs (12a, 12b) for pushing the guide rollers against the guide rails through the levers,

wherein the rigidities of the guide devices can be made variable by changing a ratio of a distance from the pivot to the spring position to a distance from the pivot to the center of the guide roller.