

ELEVATOR ROPE INSPECTION SYSTEM

FIELD

Embodiments described herein relate generally to an elevator rope inspection system.

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BACKGROUND

Machine room-less type elevators in which elevator machines such as a traction machine are accommodated in a shaft are common for space efficiency. In the machine room-less type elevator, a sheave of the traction machine is made small. Thus, as a main rope resistant against a bending wear and with a high strength rope structure, a wire rope having the surface formed of a tensile strength member coated with a resin material of wear resistant and high coefficient of friction such as polyurethane will be used.

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The wire rope of this type cannot be subjected to a strength inspection by visually inspecting the wear and tear of the wire as in a conventional wire rope because the inner tensile strength member cannot be checked visually. Thus, there is a proposed rope inspection system in which marks are put on the surface of the rope at regular intervals, and a gap between the marks with respect to a feeding amount of the rope is measured as a rope stretch, and the wear condition is determined based on the measured result to perform the strength inspection.

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In the above-mentioned rope inspection system, a rotary encoder in which a revolution part is pressed against a guide rail is used to measure the gaps between the marks on the rope surface. However, in the rotary encoder, the rotation part tends to slip because of, for example, a bump at a rail joint, a change of a coefficient of friction by an adhesive substance, and a change in a pressing force by a loading condition of the car. Thus, upward/downward movement of the car per

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predetermined distance, that is, pulse numbers with respect to a predetermined rope feeding amount vary, and measurement of gaps between the marks tends to be unreliable.

5 In another method, an encoder of a governor is used. Since the friction between the rope of the governor and the sheave is relatively stable, the pulse number does not vary widely in the encoder of the governor, and the accuracy of the measurement of gaps
10 between the marks becomes high. However, if an encoder is incorporated with the governor, an additional space including an inspection working space is required. Especially, in the machine room-less type elevator having no machine room, the governor is disposed in the
15 narrow shaft to avoid the car and the counter weight, an additional encoder disposed therein will be difficult in the layout wise.

 The present application would like to present an elevator rope inspection system which does not require
20 an additional space, can measure gaps between marks on a rope with high accuracy, and can strength inspection of high credibility.

SUMMARY

 According to one embodiment, an elevator rope
25 inspection system includes a car and a counter weight held with a traction sheave of a traction machine, in which a wear condition of a rope having a resin coated surface is inspected by measuring gaps between a plurality of marks on the surface of the rope. The
30 elevator rope inspection system includes a pulse generator, a mark detector, and a calculation device. The pulse generator generates a pulse signal in synchronization with the revolution of the traction machine. The mark detector detects each of the marks
35 on the surface of the rope, which is disposed in the

car side with respect to the traction sheave including
an engage area in the car side on the traction sheave,
or in the counter weight side with respect to the
traction sheave including an engage area in the counter
5 weight side on the traction sheave. The calculation
device calculates each gap between the marks based on a
detection timing of each mark by the mark detector and
a count value of the pulse signal generated from the
pulse generator, when driving the car in a
10 predetermined direction based on a relationship between
the position of the mark detector and the engage area.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a diagram illustrating the schematic
structure of an elevator of a first embodiment.

15 FIG. 2 is a cross-sectional view of a main rope
used in the elevator of the first embodiment.

FIG. 3 is a perspective view of the exterior of
the main rope used in the elevator of the first
embodiment.

20 FIG. 4A is a diagram illustrating pulse signals
output in synchronization with movement of the main
rope of the first embodiment.

FIG. 4B is a diagram illustrating gaps between
marks in an installing time of the first embodiment.

25 FIG. 4C is a diagram illustrating gaps between
marks when the rope is stretched because of aging of
the first embodiment.

FIG. 5 is a graph illustrating a relationship
between a stretch ratio and remaining strength of a
rope according to deterioration of the rope of the
30 first embodiment.

FIG. 6 is a diagram illustrating a relationship
between a rope tension and expansion/contraction in the
no-loading condition of the first embodiment.

35 FIG. 7 is a diagram illustrating a relationship

between a rope tension and expansion/contraction in the balanced loading condition of the first embodiment.

FIG. 8 is a diagram illustrating a relationship between a rope tension and expansion/contraction in the
5 rated loading condition of the first embodiment.

FIG. 9A is a diagram illustrating a result of a test of slipping action in a no-loading condition before the drive of the first embodiment.

FIG. 9B is a diagram illustrating a result of the
10 test of slipping action in the no-loading condition after the drive of the first embodiment.

FIG. 10A is a diagram illustrating a result of a test of slipping action in a balanced loading condition before the drive of the first embodiment.

FIG. 10B is a diagram illustrating a result of the
15 test of slipping action in the balanced loading condition after the drive of the first embodiment.

FIG. 11A is a diagram illustrating a result of a test of slipping action in a rated loading condition
20 before the drive of the first embodiment.

FIG. 11B is a diagram illustrating a result of the test of slipping action in the rated loading condition after the drive of the first embodiment.

FIG. 12 is a diagram illustrating results of
25 detection of the number of pulses generated between the marks in the upward drive/downward drive in each of the loading condition of the first embodiment.

FIG. 13 is a flowchart of the operation of a rope inspection system of the first embodiment.

FIG. 14 is a diagram illustrating a sensor
30 disposed in an engage area on the traction sheave in the car side of the first embodiment.

FIG. 15 is a diagram illustrating the schematic structure of an elevator of a second embodiment.

DETAILED DESCRIPTION

Initially, relationship between stretch ratio and strength of a rope will be explained with reference to FIG. 5 before explaining the embodiments of the present application.

For example, a wire rope used as the main rope of the elevator includes strands which are tensile strength member and core are squeezed by tension, and frictions occurs therebetween by a bent from the sheave and the like. Thus, the rope deterioration is mainly caused by the wear and tear of the wire in the proximity of the core. Because of the strand moves toward the direction of the core (as the rope diameter decreases) by the deterioration of this part, the rope is structurally stretched.

It has been discovered through a test to the wire rope having such a structure that there is a correlation between the stretch ratio and the strength as in FIG. 5. FIG. 5 shows the stretch ratio of the rope in the horizontal axis. Since it is classified, a specific value is not mentioned here, λ in the figure is a few %, that is, a few mm. The strength of the rope (which will be referred to as remaining strength ratio) is shown in the vertical axis. As the rope is gradually stretched as the time goes by, the strength decreases accordingly. In general, 80% of the strength ratio is defined as reference strength, and the rope is replaced when the stretch ratio of the rope becomes λ for better safety.

The measurement of the rope stretch is performed by feeding the rope by a predetermined length in an inspection drive, detecting marks put on the surface of the rope in the feeding, and counting a pulse signal of the encoder at the detection timing.

If the rotary encoder in which the revolution

member is pressed against the guide rail is used in the method of generating pulse signals for the mark measurement, the pulse numbers with respect to a predetermined rope feeding length vary because of a

5 bump at a rail joint, an adhesive substance, and the like, and there may probably be an error in the measurement of the gaps between the marks.

Furthermore, an encoder may be provided with the governor; however, an additional space including the inspection working space will be required.

10 Thus, a use of an encoder for traction machine revolution control which synchronizes the revolution of the traction sheave will be considered. Such an encoder does not require an additional space in the governor to accommodate the encoder, and is cost effective.

However, when the main rope is fed from the car side to the counter weight side (hereinafter will be referred to as C/W side), or is fed from the C/W side to the car side, there is a change in the tension, and the elastic stretch of the rope changes because of the change in the tension, and thus, slipping occur between the rope and the traction sheave. Because of slipping, the pulse number does not synchronize with the rope feeding, and the accuracy of the measurement of the gaps between the marks is affected.

25 Hereinafter, a method of acquiring gaps between the marks with high accuracy will be explained in consideration of the slipping action between the main rope and the traction sheave caused by a change in the tension.

(First embodiment)

FIG. 1 is a diagram illustrating the schematic structure of an elevator of a first embodiment. In the example of FIG. 1, a machine room-less type elevator

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having no machine room is considered.

A car 20 and a counter weight 21 are supported by guide rails 11 and 12, respectively, to be movable upward/downward in an elevator shaft 10. Furthermore, a traction machine 23 including a traction sheave 22 is disposed in the upper part of the elevator shaft 10. The car 20 and the counter weight 21 are suspended in the elevator shaft 10 by several main ropes 24. Note that, in FIG. 1, only a single main rope 24 is shown, and the other main ropes 24 are omitted.

Both ends of the main rope 24 are fixed to the upper end of the elevator shaft 10 via rope hitches 25a and 25b. Furthermore, the main rope 24 is continuously wound to a car sheave 26, traction sheave 22, and counter weight sheave 27 in its middle parts. Thus, the car 20 and the counter weight 21 are supported in a 2:1 roping format. When the traction sheave 22 is rotated by the drive of the traction machine 23, the car 20 and the counter weight 21 are moved upward/downward in a traction manner in the elevator shaft 10 via the main rope 24 in accordance with the traction sheave 22.

Note that, in the machine room-less type elevator, the traction machine 23 is disposed in the elevator shaft 10; however, the present invention is not limited to such a structure, and it may be applied to an elevator with a machine room. In the elevator with a machine room, the traction machine 23 is disposed in the machine room. Furthermore, the roping format is not limited to the 2:1 roping as in FIG. 1 but may be another format such as 1:1 roping.

The rope inspection system of the present embodiment includes a sensor 28, encoder 29, calculation device 30, display device 31, and controller 40.

The sensor 28 detects marks 45 (cf. FIG. 3) provided with the main rope 24 which is a target of inspection at regular intervals in the longitudinal direction. As will be described later, the marks 45
5 are detected in different positions of the main rope 24 depending on the drive direction of the car 20. That is, as illustrated by arrow A of FIG. 1, if the car 20 is driven in the upward direction, the sensor 28 is disposed in the proximity of the main rope 24 hung from
10 the traction sheave 22 to the car 20 side. The gaps between the marks detected by the sensor 28 include the elastic stretch which corresponds to a car side tension.

The encoder 29 generates a pulse signal in
15 synchronization with the revolution of the traction sheave 22. The encoder 29 is an encoder incorporated with the elevator to detect a car position and a speed. With the encoder 29 used for the measurement of the gaps between the marks, a layout problem of installing
20 the encoder in a governor can be avoided, for example.

The calculation device 30 is, for example, a computer. The calculation device 30 counts a pulse signal generated from the encoder 29 at a detection timing of each mark 45 by the sensor 28, calculates the
25 gaps between the marks from the counted value, and acquires a stretch amount of the main rope 24.

The display device 31 displays the gaps between the marks and the rope stretch amount obtained by the calculation device 30. Note that the calculation
30 device 30 and the display device 31 are a conventional computer.

The controller 40 is a control device for the general control of the elevator, and is a computer including a CPU, ROM, RAM, and the like. The
35 controller 40 detects the position of the car 20 based

on the pulse signal of the encoder 29, and moves the car 20 to a target floor at a predetermined speed. In the present embodiment, the calculation device 30 is connected to the controller 40 to obtain the pulse
5 signal of the encoder 29 from the controller 40.

Furthermore, reference number 32 in the figure indicates a landing detection member. The landing detection member 32 may be referred to as an arrival detection plate, and is provided with each floor
10 alongside the upward/downward direction of the car 20 in the elevator shaft 10. The landing detection member 32 is used to detect a stop position of the car 20 in cooperation with a contact-less switch 33 when the car 20 stops at each floor.

15 The structure of the main rope 24 will be explained with reference to FIGS. 2 and 3.

The main rope 24 is a resin-coated wire rope. As in FIG. 2, the main rope 24 includes, as its main components, a rope main body 41 as a tensile strength
20 member and an outer coating layer 42 which covers the entirety of the rope main body 41.

The rope main body 41 is formed by twisting a plurality of steel strands 43 at predetermined pitch. The outer coating layer 42 is thermoreversible resin
25 material having wear resistivity and high coefficient of friction such as polyurethane. The outer coating layer 42 includes an outer peripheral surface 42a which defines the outer surface of the main rope 24. The outer peripheral surface 42a has a circular cross-
30 sectional view, and contacts each of the sheaves 13, 15, and 16 with friction when it is wound thereto.

Furthermore, a resin material used in the outer coating layer 42 is filled in the gaps between the strands 43. Thus, the outer coating layer 42 includes
35 a plurality of charge portions 44 between the strands

43 adjacent to each other in the circumferential direction of the rope main body 41. The charge portions 44 are positioned inside the outer peripheral surface 42a of the outer coating layer 42.

5 As in FIG. 3, a plurality of marks 45 are provided with the surface of the main rope 24 (that is, the outer peripheral surface 42a of the outer coating layer 42). The marks 45 are the elements to detect a stretch amount of the main rope 24 caused by the deterioration,
10 and are aligned at regular intervals (for example, at every 500 mm) in the longitudinal direction in the entire length of the main rope 24. Each of the marks 45 is a continuous line or an intermittent line in the circumferential direction of the main rope 24.

15 Note that, as the use time of the main rope 24 goes by, gaps between the strands 43 and gaps between wires forming the strands 43 decrease. Thus, the strands 43 and the wires are repeatedly rubbed to each other, and the wear and tear of the strands 43 and the
20 wires progress.

 Specifically, the friction is repeated in the parts where the main rope 24 contacts each of the sheaves 22, 26, and 27. Thus, the wear and tear of the main rope 24 progress more in the parts as compared to
25 parts where the main rope 24 does not contact the sheaves 22, 26, and 27, and thus, the rope diameter decreases, and a local stretch occurs. Thus, the strength of the main rope 24 is controlled by clarifying a relationship between the rope stretch and
30 a strength decrease rate, and detecting the stretch in the part where is most deteriorated in the main rope 24.

 The sensor 28 is fixed in the proximity of the traction machine 23 to face the main rope 24. Thus,
35 when the car 20 is driven between the uppermost floor

and the lowermost floor in the inspection drive, the majority of the entire length of the main rope 24, except for the parts close to the rope hitches 25a and 25b, passes the sensor 28, and the marks 45 are
5 detected successively therein.

The encoder 29 outputs a pulse signal in synchronization with the movement of the car 20, and thus, a pulse output substantially corresponds to a rope feeding amount. However, in order to bring the
10 output of the pulse signal with the rope feeding amount with accuracy, an engage area of the traction sheave 22 which will be described later must be considered.

The calculation device 30 uses a mark detection signal output from the sensor 28 as a trigger, and
15 counts the number of pulse signals output from the encoder 29 to calculate the gaps between the marks from the counted value as the rope stretch amount.

The sensor 28 is, preferably, a photoelectric sensor using laser reflection light in consideration of
20 the responsibility. A commercially available photoelectric sensor irradiates the laser light onto a target and detects a change in the surface color based on the strength of the reflection light strength.

Here, when installing the elevator, the marks 45
25 are arranged in the longitudinal direction of the main rope 24 at regular intervals. Thus, if there is no stretch in the main rope 24 because of the deterioration, the count value of the pulse signal becomes substantially the same as the reference value
30 corresponding to the gaps between the marks at the installing time. On the other hand, if the main rope 24 is stretched because of the deterioration, the count value of the pulse signal exceeds the reference value corresponding to the gaps between the marks at the
35 installing time.

This will be shown in FIGS. 4A to 4C.

FIGS. 4A to 4C show a relationship between the pulse signal and the gaps between the marks. FIG. 4A indicates the pulse signals output in synchronization with the movement of the main rope 24. FIG. 4B indicates the gaps between the marks in the installing time, and FIG. 4C indicates the gaps between the marks when the rope is stretched because of aging.

If a reference value measured when the pulse signal is counted with the gaps between the marks in the installing time is given n pulse, and the main rope 24 is not deteriorated, the count value obtained in the inspection drive is substantially the same as n pulse in the installing time only with a slight difference. However, if the main rope 24 is stretched because of the deterioration, the count value obtained in the inspection drive becomes greater than n pulse corresponding to the gaps between the marks in the installing time.

Now, a method of accurately synchronizing the pulse generation by the encoder 29 and the rope feeding amount will be explained.

Here, the action of the main rope 24 wound to the traction sheave 22 will be explained with reference to examples of a no-loading condition, balanced loading condition, and rated loading condition as the loading condition of the car 20. The no-loading condition is a condition where the load of the car 20 is close to zero (user-less condition). The balanced loading condition is a condition where the load of the car 20 is substantially the same as the weight of the counter weight 21, and in this condition, when the car 20 is stopped or moves upward/downward at a constant speed, the total tension of the rope in the car side becomes equal to the total tension of the rope in the C/W side.

The rated loading condition is a condition where the load of the car 20 is close to a rating value (full condition).

FIGS. 6 to 8 are schematic views illustrating a relationship between the tension and expansion/contraction when the main rope 24 passes the traction sheave 22. FIG. 6 indicates a relationship between the rope tension and the expansion/contraction in the no-loading condition, FIG. 7 indicates a relationship between the rope tension and the expansion/contraction in the balanced loading condition, and FIG. 8 indicates a relationship between the rope tension and the expansion/contraction in the rated loading condition.

(a) No-loading condition

As in FIG. 6, in the no-loading condition, tension T_{CNL} measured when the main rope 24 is in the car side and tension T_W measured when the main rope 24 is in the C/W side is:

$$T_{CNL} < T_W$$

When the main rope 24 moves from one side to the other side, the tension changes on the traction sheave 22. Thus, elastic stretch occurring in the main rope 24 changes, and slipping occurs between the main rope 24 and the traction sheave 22.

Here, $T(\theta)$ in the figure is the tension of the main rope 24 corresponding to the position on the sheave circumference (a circumferential position represented by angle θ). If the coefficient of friction between the main rope 24 and the traction sheave 22 is given μ , as derived from a general logic of friction force transmission,

$$T(\theta) = T_{CNL} \cdot e^{\mu\theta}$$

That is, $T(\theta)$ exponentially increases as θ moves

from the low tension side to the high tension side. Note that arrows radially extending from the periphery of the sheave in the figure represent schematically the strength of the tension corresponding to the angle θ .

Furthermore, contact pressure $P(\theta)$ between the traction sheave 22 and the main rope 24 is in proportion with tension $T(\theta)$. If the groove of the traction sheave 22 is a U-letter shape, it is represented as:

$$P(\theta) = 8T(\theta) \cdot \cos\phi / \{D \cdot d \cdot \delta + \sin\delta\}$$

cf. ELEVATOR MECHANICAL DESIGN, Third Edition, ELEVATOR WORLD, INC.

Here, δ and ϕ are values to represent a cross-sectional shape of the groove of the traction sheave 22 and a contact position of the traction sheave 22 and the main rope 24 in the groove cross-section. D is a sheave diameter, and d is a rope diameter. Thus, the contact pressure $P(\theta)$ is considered to be changing on the sheave as with the change in the tension.

In the upward drive of the car 20 in the no-loading condition, the main rope 24 is conveyed from the car side where the tension is low to the C/W side where the tension is high, and thus, the elastic stretch increases on the traction sheave 22. On the other hand, in the downward drive, the main rope 24 is conveyed from the C/W side where the tension is high to the car side where the tension is low, and thus, the elastic stretch decreases on the traction sheave 22.

(b) Balanced loading condition

As in FIG. 7, in the balanced loading condition, the static tension becomes equal in the car side and the C/W side. Thus, a relationship between tension T_{CBL} in the car side and tension T_W in the C/W side is represented as follows.

$$T_{CBL}=T_W$$

Tension $T(\theta)$, and contact pressure $P(\theta)$ become substantially constant on the sheave regardless of the angle θ , and the stretch on the sheave in the upward drive/downward drive becomes substantially constant.

(c) Related loading condition

As in FIG. 8, in the related loading condition, the relationship between tension T_{CFL} in the car side and tension T_W in the C/W side becomes opposite to the no-loading condition.

$$T_{CFL}>T_W$$

As the angle θ expands from the low tension side to the high tension side, $T(\theta)$ exponentially increases as in the no-loading condition.

$$T(\theta)=T_{CNL}\cdot e^{\mu\theta}$$

The same change applies to the contact press $P(\theta)$. Thus, in the rated loading condition, the elastic stretch decrease when the main rope 24 is conveyed to the C/W side in the upward drive, and the elastic stretch increases in the downward drive.

From the above, it is considered that there is slipping between the traction sheave 22 and the main rope 24 in the conditions other than the balanced loading condition. On the other hand, the number of sheave rotations corresponding to the car movement distance in the upward drive and the downward drive is substantially constant in the same loading condition. Thus, it is considered that there is an area on the traction sheave 22 where no slipping occurs between the main rope 24 and the traction sheave 22 and are moved integrally while engaging with each other. This area will be referred to as an engage area.

As described later, the engage area is in a winding up side of the traction sheave 22. The winding

up side is a side to which the main rope 24 is wound by the rotation of the traction sheave 22, and it is in the car side in the upward drive and in the C/W side in the downward drive. The engage area is an area moving
5 from the time when the main rope 24 contacts the groove formed in the peripheral part of the traction sheave 22 while engaging the groove without slipping. FIGS. 6 to 8 do not illustrate an engage area; however, it is in the car side (C/W side) adjacent to the area of angle θ
10 in the upward drive (downward drive). Note that the length of the engage area depends on the size and the material of the sheave and the rope, car weight, C/W weight, and the like.

Now, hypothetically, if there are several engage
15 areas on the traction sheave 22, the sheave peripheral speed is the same in parts where the rope stretches are different, and the rope is conveyed at different rates in the engage areas. Thus, there are no multiple engage areas structurally, and there is only one on the
20 traction sheave 22.

As described above, the contact pressure $P(\theta)$ is in proportion with the tension, and differs depending on the positions of the traction sheave 22. Thus, it is considered that, if the surface layer is formed of
25 an easily deformable resin as with the resin coated rope, the pressure deformation amount of resin changes depending on the positions of the engage areas, and the number of sheave rotations with respect to the rope conveying amount, that is, the number of revolution of
30 the encoder 29 in synchronization with the traction sheave 22 changes.

Thus, in order to accurately calculate the rope conveying amount corresponding to the gaps between the marks based on the number of pulses of the encoder 29
35 which is in synchronization with the sheave rotation,

the position of the engage area must be grasped. In order to grasp the position of the engage area, the following tests were performed.

(Test 1)

5 A result of a test of a slipping action between the traction sheave 22 and the main rope 24 will be explained. FIGS. 9A and 9B show a result of a test of the slipping action in the no-loading condition. FIGS. 10A and 10B show a result of a test of the
10 slipping action in the balanced loading condition. FIGS. 11A and 11B show a result of a test of the slipping action in the rated loading condition.

 In the test, initially, the car 20 is stopped at the lowermost floor, and match marks Ms and Mp are
15 provide with the traction sheave 22 and the main rope 24 at positions corresponding to each other on the periphery. Then, the car 20 is cycled once, and a shift between the match marks Ms and Mp is observed.

 In the present test, a cycle drive is performed,
20 as in the general drive method of elevators, from a state where the car 20 is stopped at the lowermost floor moving to a state where the car 20 is stopped at the uppermost floor by the landing control of the car 20. As a result, the match mark Mp in the rope side is
25 always shifted from the match mark Ms in the sheave side to the greater tension direction. That is, in the no-loading condition, the match mark Mp in the rope side is shifted from the match mark Ms in the sheave side in the C/W side direction (cf. FIGS. 9A and 9B).
30 In the rated loading condition, the match mark Mp in the rope side is shifted from the match mark Ms in the sheave side in the car side direction (cf. FIGS. 11A and 11B). On the other hand, in the balanced loading condition in which the tension in the car side and the
35 tension in the C/W side are equal, there is no shift

between the match marks Ms and Mp (cf. FIGS. 10A and 10B). Note that, if there is no change in the loading condition, a shift between the match marks Ms and Mp per cycle drive becomes substantially constant, and the shift increases when the process of the cycle drive becomes longer.

From the above, a shift between the match marks Ms and Mp apparently indicates that the engage area exists in the winding up side of the traction sheave 22 with respect to the rope tension change area on the traction sheave 22.

The shift between the match marks Ms and Mp apparently occurs because the number of sheave revolution differs between the upward drive and the downward drive with respect to a regular drive process. That is, the engage area is generated in the winding up side of the traction sheave 22, and the number of revolution at the time of winding up the rope in the greater tension side becomes greater than the number of revolution at the time of winding up the rope in the smaller tension side, and thus, the shift between the match marks Ms and Mp is generated in one cyclic drive.

For example, in the no-loading condition, the upward drive is performed with the number of revolution which ascends the car 20 by a predetermined distance by winding up the rope in the car side stretch of which is small. The downward drive is performed with the number of revolution which descends the car 20 by the same distance as in the upward drive by winding up the rope in the C/W side stretch of which is great. At that time, if the engage area is in the winding up side, the shift shown in FIGS. 9A and 9B occurs.

(Test 2)

FIG. 12 indicates a result of counting the pulse signal of the encoder 29 based on the gaps between the

marks in the upward drive and the downward drive in each loading condition. Note that, in this test, as with the structure of FIG. 1, the sensor 28 to detect the marks 45 is disposed in the car side of the main rope 24.

FIG. 12 indicates a drive condition (a loading condition and a drive direction) in the horizontal axis, and the number of pulses generated in the gaps between the marks in each of the drive condition in the vertical axis.

The number of pulses are measured per loading condition with respect to the gaps between the marks 45 provided at regular intervals in the longitudinal direction of the main rope 24. In the figure, Nd, Bd, and Fd indicate ranges of the result measured when the car is driven downward in each of the no-loading condition, balanced loading condition, and rated loading condition. Nu, Bu, and Fu indicate ranges of the measurement result when the car is driven upward in each of the no-loading condition, balanced loading condition, and rated loading condition.

The detection of the marks 45 is performed in the rope in the car side as in the structure shown in FIG. 1, and thus, the gaps between the marks include an elastic stretch corresponding to the loading condition. Furthermore, the resin is deformed differently by the pressure depending on the position of the engage area on the traction sheave 22, and thus, it is considered that the number of revolution of the encoder 29 in synchronization with the traction sheave 22 will be different depending on the position of the engage area. From the results of the test in FIG. 12, it is understood that the number of pulses obtained in the downward drive does not show dependence on the loading condition, and the number of pulses obtained in the

upward drive increases corresponding to the loading condition.

Now, hypothetically, if the engage area on the traction sheave 22 is in the winding up side, it is interpreted that the engage area is in the car side in the upward drive and in the C/W side in the downward drive. Furthermore, in the upward drive, the number of revolution corresponds to the contact pressure in proportion to the tension in the car side, and the resin deformation by pressure becomes small in the no-loading condition where the contact pressure is smaller (the radius around which the rope is conveyed is greater), and thus, it is interpreted that the number of revolution (number of pulses) becomes less. On the other hand, in the downward drive, the tension in the C/W side is constant, and thus, the number of revolution (number of pulse) is not dependent on the loading condition.

Furthermore, even the gaps between the marks include the elastic stretch corresponding to the loading condition, there is no effect of the loading condition on the number of pulses generated in the downward drive in the test result of FIG. 12. It is considered this is because the elastic coefficient of the resin-coated rope which is dominantly influenced by the inner rope structure is greater as compared to the tension difference caused by the loading condition, and the amount of the elastic stretch with respect to the gaps between the marks is small, and thus, the effect of the loading condition is not so obvious.

From the results of the above-mentioned two tests, the following conclusions are derived.

(1) When the number of pulses corresponding to the gaps between the marks are generated, if the loading condition is other than the balanced loading condition,

the number of revolution of the traction sheave 22 differs between the upward drive and the downward drive with respect to a predetermined car movement distance.

5 (2) The engage area of the traction sheave 22 in synchronization with the rope feeding is generated in the winding up side.

In order to accurately calculate the rope feeding amount corresponding to the gaps between the marks based on the number of pulses of the encoder 29 in
10 synchronization with the revolution of the traction sheave 22, above (1) and (2) must be considered.

In the operation of the rope inspection system, in order to reduce the workload, an inspection method in which no load exists in the car 20, that is, inspection
15 in the no-loading condition is desirable. As in the example of FIG. 1, if the sensor 28 is in the car side with respect to the traction sheave 22, it is desired that the pulses are generated from the encoder 29 in the upward drive. In contrast, if the sensor 28 is in
20 the C/W side with respect to the traction sheave 22, it is desired that the pulses are generated from the encoder 29 in the downward drive.

Now, the operation of the system will be explained.

25 FIG. 13 is a flowchart of the operation of the present system, and indicates a process of automatic measurement of the gaps between the marks 45 in the inspection drive.

The controller 40 drives the car 20 in a
30 predetermined direction in consideration of a relationship between the position of the sensor 28 and the engage area of the traction sheave 22 (step S11). The predetermined direction is either the upward direction or the downward direction, and is determined
35 based on the position of the sensor 28.

As described above, the engage area exists in the winding up side of the traction sheave 22. Thus, if the sensor 28 is disposed in the car side with respect to the traction sheave 22, it is desired that the pulse is generated from the encoder 29 driving the car 20 in the upward direction. Furthermore, if the sensor 28 is disposed in the C/W side with respect to the traction sheave 22, it is desired that the pulse is generated from the encoder 29 driving the car 20 in the downward direction. In the example of FIG. 1, the sensor 28 is disposed in the car side with respect to the traction sheave 22, and thus, the car 20 is driven to the upward direction. At that time, the car 20 is in the no-loading condition.

During the drive of the car 20, the calculation device 30 acquires the pulse signals output from the encoder 29 through the controller 40, and orderly counts the number of the pulse signal (step S12).

Furthermore, in accordance with the movement of the main rope 24, marks 45 on the surface of the rope are optically detected by the sensor 28 (step S13). The calculation device 30 checks a current count value of the pulse signal at the time when the marks 45 are detected by the sensor 28, and calculates gaps between the marks based on the count value (step S14).

Specifically, the calculation device 30 includes a pulse rate which defines a length of the main rope 24 conveyed per pulse. The calculation device 30 counts the number of the pulse signal generated by the encoder 29 while the marks 45 are detected by the sensor 28, and multiply the count value by the pulse rate to calculate the gaps between the marks. The gaps between the marks calculated here are stored in the memory 30a in the calculation device 30 (FIG. 1). In that case, if the main rope 24 is not stretched, the calculated

gaps between the marks are the same as the gaps between the marks put on the main rope 24 in the installing time (for example, 500 mm). When the main rope 24 is stretched because of aging, the calculated gaps between the marks become greater than the gaps between the marks in the installing time.

Thereinafter, in the similar manner, the count value of the pulse signal is acquired at the detection timing of the marks 45 while the car 20 moves a predetermined distance, and the gaps between the marks are sequentially calculated from the count values to be stored in the memory 30a (steps S12 to S15). The predetermined distance is a distance of a cycle drive between the lowermost floor and the uppermost floor, or a distance of a cycle drive between the uppermost floor and the lowermost floor.

Note that, as a count method of the pulse signal, there is a method of adding pulses one-by-one from an initial value (for example, 0000), or a method of repeating counts while resetting the count to an initial value every time the mark is detected. In the first method, a difference between the total value of the pulses when the mark 45 is detected and the total value of the pulse when the mark 45 is detected last is derived, and the gaps between the marks are acquired from the difference.

In order to associate the rope position with the car position, a method to adding up the pulses one-by-one from the initial value as in the first method is preferred. In that case, if the total value of the pulses when the marks 45 are detected are stored sequentially, and the car 20 is moved using the total value as an index, the part to be checked in the main rope 24 can be visually checked at the position of the sensor 28.

Here, in the installing time of the elevator, the marks 45 are arranged at regular intervals in the longitudinal direction of the main rope 24. Thus, if there is no stretch of the main rope 24 because of deterioration, the count value of the pulse signal becomes substantially the same as the reference value corresponding to the gaps between the marks in the installing time. On the other hand, if the main rope 24 is stretched by the deterioration, the count value of the pulse signal exceeds the reference value corresponding to the gaps between the marks (cf. FIGS. 4A to 4C).

After the inspection drive, the calculation device 30 calculates the stretch amount of the main rope 24 based on the gaps between the marks stored in the memory 30a as a result of the measurement (step S16), and displays the result on the display device 31 (step S17).

Note that the stretch amount may not be calculated by the calculation device 30 but the gaps between the marks may be displayed on the display device 31. Furthermore, a time to replace the rope may be notified to a service man by a message is displayed on the display device 31 or an alarm sound is issued if the gap between the marks is exceeds a reference value, for example. Thereby, the inspection operation by a service man can be decreased, and the time to require the rope replacement can be grasped more effectively.

Furthermore, it is easy to associate the measurement value of gaps between the marks of each part with the rope movement amount in the inspection drive from the count value of the pulse signal, and thus, the rope position exceeding the reference value may be displayed on the display device 31. The position of the gap between marks which exceeds the

reference value is a part with more damage, and should be visually checked in order to clarify the cause of the damage. In such a case, the position of the rope which exceeds the reference value is displayed for easier visual check.

Furthermore, the position where the main rope 24 is stretched the most, that is, the maximum gap between the marks may be displayed on the display device 31. In general, the position most deteriorated in the main rope 24 is the part where a bending load which is associated with a floor to which the car 20 stops most frequently becomes maximum. However, for example, if there is a part erroneously damaged during the installing, for example, the deterioration of the damaged part may be progressed faster. By displaying the position of the rope which is stretched the most, a possible deteriorated part which is different from the ordinary deterioration can be easily checked.

Furthermore, the results of mark measurement may be stored in the memory 30a as history, and the history per inspection date may be displayed as a graph. With such history, the deterioration condition of the rope can be easily grasped from the changes in the gaps between the marks.

Furthermore, if the history is periodically sent to a remote elevator monitoring center which is not shown, the wear condition of the main ropes 24 in many buildings can be managed at the elevator monitoring center, and the building with the rope which should be replaced soon can be notified to a service man.

As above, by driving the car 20 in a predetermined direction based on the relationship between the position of the sensor 28 and the engage area of the traction sheave 22, the number of pulses with respect to the rope feeding can be synchronized with accuracy,

the gaps between the marks can be measured from the pulse number with high accuracy, and the wear condition of the rope can be determined.

5 Note that, in the operation of the rope inspection system, the rope thinning caused by the deterioration of the inner structure of the resin-coated rope should be considered as a cause of decreasing the accuracy of the measurement of the gaps between the marks. That is, the deterioration of the rope is mainly caused by
10 the wear and tear of the strands in the proximity of the core of the rope. When this part is deteriorated, the strands 43 shown in FIG. 2 move toward the core, and the rope diameter is decreased (that is, the rope is thinned). If the rope diameter is decreased by
15 aging, the number of revolutions of the encoder 29 with respect to the rope feeding amount increases as in the pressure deformation of the resin coat.

 Then, in order to chronically maintain the accuracy of measurement of the gaps between the marks,
20 the pulse rate used in the calculation of the gaps of the marks should be adjusted based on the operation time of the elevator. In that case, as the operation time of the elevator is longer, the rope thinning progresses, and the number of revolution of the encoder
25 29 increases, and value of pulse rate (mm/pulse) needs to be reduced. Specifically, in step S14 of FIG. 13, the calculation device 30 checks the current operation time of the elevator, and adjusts the value of the pulse rate to be smaller corresponding to the operation
30 time, and calculates the gaps between the marks using the adjusted pulse rate.

 Furthermore, the rope thinning depends on the deterioration floor of the inner structure, and is not uniform in the entire length of the rope. That is, in
35 the floor where the car 20 is frequently stopped

(reference floor or the like), the bending load is frequently applied to the position where the main rope 24 is wound on the traction sheave 22, and thus, the rope thinning in this position is progressed more.

5 Thus, the gaps between the marks should be calculated while changing the pulse rate per car position. In that case, the rope thinning is progressed more in the floor where the car 20 is stopped more frequently, and thus, the pulse rate corresponding to this floor should
10 be smaller than that of the other floors.

Specifically, in step S14 of FIG. 13, the calculation device 30 acquires floor information of the car 20 from the controller 40, and adjusts the pulse rate per floor based on the floor information, and calculates the gaps
15 between the marks by multiplying the count value of the pulse signal by the adjusted pulse rate.

Furthermore, the setting of the pulse rate should be changed, in consideration of the actions of the tension and contact pressure in the passing of the
20 sheave, between a case where the sensor 28 is disposed in the car side with respect to the traction sheave 22 and a case where it is disposed in the C/W side.

That is, if the sensor 28 is disposed in the car side with respect to the traction sheave 22, the
25 movement distance of the car 20 which is regarded as a substantially constant distance during the use thereof is divided by the number of pulses obtained in the upward drive of the car 20, and the value obtained is used as the pulse rate.

30 In contrast, if the sensor 28 is disposed in the C/W side with respect to the traction sheave 22, the movement distance of the counter weight 21 which is regarded as a substantially constant distance during the use thereof is divided by the number of pulses
35 obtained in the downward drive of the car 20, and the

value obtained is used as the pulse rate. That is, when the sensor 28 is disposed in the C/W side and the rope of the C/W side tension is measured, the car movement distance and the length of the rope passing in the C/W side differ in the loading condition than the balanced loading condition. Thus, in a case where the pulse rate is adjusted (corrected) in the structure where the sensor 28 is disposed in the C/W side, the movement distance of the counter weight 21 which is regarded as a substantially constant distance during the used thereof is divided.

As the movement distance of the car 20 which is regarded as a substantially constant distance during the use thereof, a distance of the guide rail 11 size of which is clear can be used. Or, the gaps between the landing detection members 32 of the floors in the elevator shaft 10 may be used. Furthermore, the movement distance of the counter weight 21 which is regarded as a substantially constant distance during the use thereof, a distance of the guide rail 12 size of which is clear can be used. By using such conventional elevator components, an additional device used to calculate the pulse rate is not necessary, and thus, the cost-effective structure can be achieved.

Note that, in FIG. 1, the sensor 28 is disposed to be apart from the traction sheave 22; however, the sensor 28 can achieve the same effect even on the traction sheave 22 as long as it is in the position including the engage area in the car side or the C/W side.

FIG. 14 illustrates an example where the sensor 28 is disposed in an engage area Ec on the traction sheave 22 in the car side. In this case, the car 20 is driven upward (driven in the direction of arrow A), and the gaps between the marks on the main rope 24. If the

sensor 28 is disposed in the proximity of the engage area Ec on the traction sheave 22 in the car side as above, the gaps between the marks can be measured with high accuracy without intervening the upward/downward movement of the car 20. Similarly, the sensor 28 may be disposed in the engage area of the traction sheave 22 in the C/W side, and the car 20 may be driven downward. Thereby, the gaps between the marks can be measured with high accuracy without intervening the upward/downward movement of the counter weight 21.

(Second embodiment)

Now, a second embodiment will be explained.

In the first embodiment, in order to generate pulses in synchronization with the rope feeding amount, the encoder 29 for traction machine revolution controlling is used since it is excellent in the layout and cost-effectiveness wise. The encoder 29 is a rotary encoder, and instead thereof, a linear encoder which detects a movement distance of the car 20 or the counter weight 21 in a magnetic or optical manner and outputs the pulse may be used.

As the pulse generator, the same effect can be achieved with the structure to generate the pulse signal in substantial synchronization with the feeding amount of the main rope 24, that is, the structure to generate the pulse signal in accordance with the upward/downward movement of the car 20 or the counter weight 21.

Now, the structure to generate pulses using a non-contact laser range finder will be explained.

FIG. 15 is a diagram illustrating the schematic structure of the elevator of the second embodiment. Elements common with those shown in FIG. 1 will be referred to by the same reference numbers, and the detailed description thereof will be omitted.

A non-contact type laser range finder 34 is disposed on the bottom part of the car 20 to face a fixation part 35. The laser range finder 34 includes a light irradiator 34a and a light receiver 34b to
5 irradiate laser beam from the light irradiator 34a to the fixation part 35 and to receive the light reflected by the fixation part 35 by the light receiver 34b in order to measure a movement distance of the car 20. The fixation part 35 is disposed in the pit within the
10 elevator shaft 10 to face the laser range finder 34, for example.

The laser range finder 34 has only a few mm error in the measurement of approximately 100 m. Thus, by using the laser range finder 34 as a linear encoder and
15 generating the pulse signal in synchronization with the movement distance of the car 20, the gaps between the marks of the main rope 24 can be measured with high accuracy.

The operation in the measurement is similar to
20 that of the first embodiment described above. That is, the car 20 is driven in a predetermined direction based on the relationship between the position of the sensor 28 and the engage area of the traction sheave 22. Thus, the number of pulses with respect to the rope
25 feeding can be synchronized with accuracy, and the gaps between the marks can be measured from the pulse number with high accuracy, thereby making it possible to determine the wear condition of the rope.

Note that, in the example of FIG. 15, the laser
30 range finder 34 is provided with the car 20 and the pulse signal is generated in synchronization with the movement distance of the car 20; however, the laser range finder 34 may be provided with the counter weight 21, and the pulse signal may be generated in
35 synchronization with the movement distance of the

counter weight 21.

Furthermore, the sensor 28 is disposed to be apart from the traction sheave 22 in the example of FIG. 15; however, the same effect can be achieved even if the
5 sensor 28 is disposed on the traction sheave 22 within the position including the engage area in the car side or the C/W side.

According to one or more embodiments described above, an elevator rope inspection system which does
10 not require an additional space to be installed, and can measure gaps between marks on a rope with high accuracy to perform management of rope strength with high credibility can be achieved.

While certain embodiments have been described,
15 these embodiments have been presented by way of example 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
20 changes in the form of the embodiments described herein 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
25 of the inventions.

WHAT IS CLAIMED IS:

1. An elevator rope inspection system in which a car and a counter weight are held with a traction sheave of a traction machine, and a wear condition of a rope having a resin coated surface is inspected by measuring gaps between a plurality of marks on the surface of the rope, the system comprising:

a pulse generator configured to generate a pulse signal in synchronization with the revolution of the traction machine;

a mark detector configured to detect each of the marks on the surface of the rope, which is disposed in the car side with respect to the traction sheave including an engage area in the car side on the traction sheave, or in the counter weight side with respect to the traction sheave including an engage area in the counter weight side on the traction sheave; and

a calculation device configured to, when driving the car in a predetermined direction based on a relationship between the position of the mark detector and the engage area, calculate each gap between the marks based on a detection timing of each mark by the mark detector and a count value of the pulse signal generated from the pulse generator.

2. The elevator rope inspection system of claim 1, wherein, if the mark detector is disposed in the car side, the calculation device calculates each gap between the marks using the pulse signal generated from the pulse generator when the car is driven upwards.

3. The elevator rope inspection system of claim 1, wherein, if the mark detector is disposed in the counter weight side, the calculation device calculates each gap between the marks using the pulse signal generated from the pulse generator when the car

is driven downwards.

4. The elevator rope inspection system of claim 1, wherein the calculation device has a pulse rate defining a length of the rope to be fed per one pulse and calculates each gap between the marks by multiplying the pulse rate on the count value of the pulse signal.

5. The elevator rope inspection system of claim 4, wherein the calculation device adjusts the pulse rate corresponding to an operation time of the elevator.

6. The elevator rope inspection system of claim 4, wherein the calculation device adjusts the pulse rate corresponding to a position of the car.

7. The elevator rope inspection system of claim 4, wherein the pulse rate is calculated, if the mark detector is disposed in the car side, by dividing a movement distance of the car which is regarded to be substantially constant with time with the pulse number derived from the upward drive of the car.

8. The elevator rope inspection system of claim 4, wherein the pulse rate is calculated, if the mark detector is disposed in the counter weight side, by dividing a movement distance of the counter weight which is regarded to be substantially constant distance with time with the pulse number derived from the downward drive of the car.

9. The elevator rope inspection system of claim 7, wherein a reference to the substantially constant distance is a length of a guide rail supporting the car, or a gap between a plurality of landing detection members provided with each floor in a shaft.

10. The elevator rope inspection system of claim 8, wherein a reference to the substantially

constant distance is a length of a guide rail supporting the counter weight.

11. An elevator rope inspection system in which a car and a counter weight are held with a traction sheave of a traction machine, and a wear condition of a rope having a resin coated surface is inspected by measuring gaps between a plurality of marks on the surface of the rope, the system comprising:

a pulse generator configured to generate a pulse signal in synchronization with a movement distance of the car or the counter weight;

a mark detector configured to detect each of the marks on the surface of the rope, which is disposed in the car side with respect to the traction sheave including an engage area in the car side on the traction sheave, or in the counter weight side with respect to the traction sheave including an engage area in the counter weight side on the traction sheave; and

a calculation device configured to, when driving the car in a predetermined direction and generating a pulse signal in synchronization with the movement distance of the car or the counter weight from the pulse generator according to the position of the mark detector, calculate each gap between the marks based on a detection timing of each mark by the mark detector and a count value of the pulse signal generated from the pulse generator.

12. The elevator rope inspection system of claim 11, wherein, if the mark detector is disposed in the car side, the calculation device has the pulse generator generate a pulse signal in synchronization with the movement distance of the car, and calculates each gap between the marks using the pulse signal.

13. The elevator rope inspection system of claim 11, wherein, if the mark detector is disposed in

the counter weight side, the calculation device has the pulse generator generate a pulse signal in synchronization with the movement distance of the counter weight, and calculates each gap between the marks using the pulse signal.

14. The elevator rope inspection system of claim 11, wherein the pulse generator is a laser range finder configured to optically measure the movement distance of the car or the counter weight.