

TITLE OF THE INVENTION

APPARATUS AND METHOD FOR INSPECTION OF CONTINUOUS MEMBER USED
FOR TRANSPORT MECHANISM INCLUDING STEEL CORD

5 FIELD OF THE INVENTION

The present invention relates to an apparatus and a method
for inspection of a continuous member, such as a handrail of
a passenger conveyor including an escalator, a moving sidewalk,
and the like, a wire rope for elevator, and the like, used for
10 transport mechanism. In particular, it relates to an apparatus
and a method for inspection of a continuous member for transport
mechanism including a steel cord.

BACKGROUND OF THE INVENTION

15 A passenger conveyor such as an escalator, a moving
sidewalk and the like, is provided with a handrail as a railing
moved in synchronization with stairs for carrying passengers.
Passengers hold on this handrail to stabilize themselves. Such
a handrail is structured by holding a steel belt comprising
20 a member of steel cords (hereafter, abbreviated as SC in some
cases) with a rubber holder and then further covering an exterior
of the steel belt with a decorative rubber.

Each steel cord is configured by helically laying up a
number of strands each formed by stranding a number of individual
25 wires together. When this steel cord is deteriorated with age,

the strand comes undone and a part of wires may protrude from the steel cord. Hereafter, such a state in which the wire is protruded from the steel cord by way of the above course will be referred to as "individualized wire (or coming undone-steel cord)" of the steel cord. At this stage, however, the wire is not yet protruded from an outer covering namely the decorative rubber in many cases.

When a passenger conveyor is in operation, the handrail and the steel cords incorporated therein are repeatedly bent by the action of a driving apparatus. Then "individualized wire" eventually occurs. Whether or not age deterioration of any steel cord has appeared can be diagnosed by the presence or absence of this "individualized wire." In addition, the degree of advancement of deterioration can be determined according to length where an area with this "individualized wire" continues in a direction of the length of the handrail.

Patent Document 1 (JP-A-Hei 11(1999)-325844) discloses a method of applying light to a crane rope to be diagnosed, receiving a projected light resulting from the applied light with a photo receiver to convert the amount of received light into a signal, and converting fluctuation in this signal output into a spectrum to judge a state of deterioration (wire break, wear, shape losing, elongation) of wires.

Patent Document 2 (JP-A-2009-12903) discloses an apparatus and a method as a wire break detecting means of

detecting a wear splinter appeared in wires from a rope image shot with a camera and detecting any deterioration in the wire rope from the number of the wear splinter.

Patent Document 3 (JP-A-2008-214037) discloses a method
5 of arranging a laser projector and a photo receiver such that a wire rope is set therebetween, measuring an outside diameter of the wire rope from an output signal to the photo receiver that receives the laser projected thorough the wire rope, and detecting any deterioration from fluctuation in periodicity
10 of a change in the measured outside diameter.

Patent Document 4 (JP-A-Hei 10(1998)-10060) discloses, as a procedure for diagnosing deterioration in any steel cord of a handrail for passenger conveyor, of shooting for the handrail with the steel cords incorporated therein by using
15 X-ray inspection apparatus while moving the apparatus as required, and thereby visually inspecting a state of the steel cord.

Patent Document 5 (JP-A-2005-126175) discloses of calculating a power spectrum, which is a square of a
20 two-dimensional Fourier spectrum, from X-ray images shot with a configuration similar to that in Patent Document 4, and thereby automatically determining as to evenness of each distance between multiple arranged steel cords and as to presence or absence of meandering from a pattern of this power spectrum.

25 Patent Document 6 (JP-A-2008-309649) discloses the

following method though it is not for diagnosing deterioration in any steel cord of a handrail for passenger conveyor. That is, disclosed is of shooting for a steel belt in a rubber tire with X-rays, combining those X-ray images continuously shot
5 in a direction of circumference of the tire to form a panoramic image, and then processing the panoramic image to extract an outline of the steel belt, further measuring a width of the steel belt at equal intervals in a direction orthogonal to the circumference, and when the width is discontinuous, determining
10 that the steel has damage.

The following document list presents non-patent Documents 1 and 2 aside from the above-mentioned patent documents. These non-patent documents are utilized in spatial filtering in part of image processing in a working example of the invention
15 described later and will be described in the section of the working example.

In order to appropriately make good timing of replacement of a handrail of a passenger conveyor, it is necessary to accurately diagnose the degree of such deterioration. A
20 handrail of a passenger conveyor is prone to be gradually deteriorated with age and "individualized wire" may occur in any steel cord built therein. Under the present circumstances, if it can be automatically detected whether or not "individualized wire" has occurred and over how length the
25 "individualized wire" has occurred in a direction of the length

of the handrail, it is possible to automatically diagnose as to deterioration of the handrail.

The technology disclosed in Patent Document 1 is based on the following knowledge. That is, regarding the amount of received light resulting from projection of light to a wire rope of a crane or an elevator, the wire rope having a normal strand state since has a periodical fluctuation in the width of the rope silhouette, and when converting the amount of received light to the signal and detecting the fluctuation deviating from periodical fluctuation from the signal, deterioration of the rope can be judged (In this case, an unspecified frequency spectrum is generated). In the case of a rope being used for a cranes or an elevator, it since is continuous without a break, when the fluctuation of its silhouette deviates from periodical fluctuation, it can be judged as an anomaly. On the other hand, in the case of a handrail of a passenger conveyor, it has a gap at a seam of a built-in steel cord normally and the fluctuation of its silhouette is non-periodical due to the gap resulting in deviation from periodical fluctuation even when they are not deteriorated. Therefore, this deterioration judgment method may be unsuitable in some cases.

In the technology disclosed in Patent Document 2, the number of wear splinter of a wire is imaged from each frame of an ITV image taken in by an industrial television and a wire break

is detected from the number of wear splinter. However, the patent document does not concretely disclose as to image processing for detecting the number of wear splinter.

In the technology disclosed in Patent Document 3, change
5 in the outside diameter of a wire rope is measured by projecting laser beam. This is unsuitable for diagnose of such a handrail that has a gap in a steel cord even though it is not deteriorated like the technology in Patent Document 1. The technology does not take the detection of "individualized wire" important for
10 deterioration judgment into account.

In the technology disclosed in Patent Document 4, any deterioration in a wire rope or a steel cord is judged by visual check by maintenance personnel. Therefore, unevenness judgments are prone to be generated because of the difference
15 in judgment among maintenance individuals.

In the technology disclosed in Patent Document 5, unevenness in steel cords and the presence or absence of meandering are quantitatively determined from a power spectrum. Unevenness in a built-in steel cord and meandering are also
20 observed in non-deteriorated handrail. Therefore, according to such a technology, it is difficult to judge the presence or absence of any deterioration in a steel cord itself. The patent document does not take a technology for detecting "individualized wire" important for deterioration judgment
25 into account at all.

The technology disclosed in Patent Document 6 is that:
on the assumption that the width of a steel belt of a normal
tire is constant, when a measurement value of the width of the
steel belt departs from a predetermined range, the tire is judged
5 to have damage. With respect to steel cords built in handrail,
meanwhile, the range within which they have usually meandering
or fluctuation in a direction orthogonal to the direction of
length. Therefore, the presence or absence of deterioration
in any steel cord cannot be judged by this technology. This
10 patent document does not disclose a technology for detecting
"individualized wire" required in deterioration judgment at
all, either.

Up to this point, introduced are several publicly known
technologies knowable to the present applicants, and among them,
15 a technology for automatically diagnosing the state of
deterioration (wire break, wear, shape losing, elongation) of
any steel cord such as a wire rope although has been proposed
as in Patent Document 1, they are unsuitable for deterioration
diagnose of any steel cord of the handrail for passenger conveyor
20 as mentioned above. A technology of detecting especially as
to "individualized wire" of any steel with accuracy has not
been proposed yet.

The invention is proposed in consideration of the
above-mentioned circumstances, and its object is to provide
25 an inspection apparatus for a continuous member used for

transport mechanism, namely, the inspection apparatus capable of automatically and accurately detecting and/or diagnosing especially as to the "individualized wire" (coming-undone steel cord) of a steel cord included in the continuous member which is, for example, not only handrail of the passenger conveyor but also continuous members of transport mechanism other than the passenger conveyor.

SUMMARY OF THE INVENTION

10 To achieve the above object, the invention as to Claim 1 is basically an inspection apparatus for continuous member including a steel cord, which is used in a transport mechanism, configured by helically laying up plural individualized wires. The inspection apparatus is comprised of:

15 (i) an imaging unit that applies X-rays or visible light to form a projected image of the steel cord as an object of inspection; and

(ii) an image processing unit that receives the projected image from the imaging unit, carries out image processing upon the projected image and detects an individualized wire protruding from the steel cord coming undone with extracting a line segment thinner than a normal steel cord and higher in brightness than the normal steel cord from the projected image.

25 According to the present invention as to Claim 1, it is possible to automatically and accurately detect and/or diagnose

especially as to the "individualized wire" (coming undone-steel cord) of the steel cord of not only handrail of the passenger conveyor and the like but also continuous members of transport mechanism other than the passenger conveyor.

5 Incidentally, the other effects of the invention in other claims depending on Claim 1 in this application will be apparent from the description in the whole of this specification.

BRIEF DESCRIPTION OF THE DRAWINGS

10 FIG. 1 is a drawing illustrating a flow of wire detection processing in an inspection apparatus of the present invention for handrail of a passenger conveyor;

 FIG. 2 is a drawing illustrating an example of a line segment detection filter of the inspection apparatus of the
15 present invention for handrail of the passenger conveyor;

 FIGS. 3A to 3C are drawings illustrating an example of a line segment aggregation image in the inspection apparatus of the invention for the handrail of the passenger conveyor;

 FIG. 4A is a schematic diagram illustrating an example
20 of a configuration of the inspection apparatus for handrail of the passenger conveyor in this working example in state that the inspection apparatus is set on the handrail during inspection;

 FIG. 4B is a schematic diagram illustrating an example
25 of the equipment configuration of the inspection apparatus for

the handrail of passenger conveyor of the invention and how it is set on a handrail from a viewpoint different from that in FIG. 4A;

FIG. 5 is a drawing illustrating an example of an X-ray
5 image of a handrail shot with then inspection apparatus for the handrail of passenger conveyor of the invention;

FIG. 6 is a conceptual rendering of an X-ray image of a good state -handrail by an inspection apparatus for the handrail of passenger conveyor of the invention;

10 FIGS. 7A to 7C are conceptual renderings of an X-ray image of a handrail in the initial stage of deterioration by the inspection apparatus for the handrail of passenger conveyor of the invention;

FIG. 8 is a drawing illustrating an example of an imaging
15 system;

FIG. 9 is a drawing explaining the brightness distribution of an image formed by an ordinary steel cord;

FIG. 10 is a drawing explaining the brightness distribution of an image formed by a thin steel cord with
20 "individualized wire";

FIG. 11 is a drawing explaining the brightness distribution of an image formed by a steel cord having a borderline outside diameter;

FIG. 12 is a drawing explaining the brightness
25 distribution of an image formed by a steel cord having a

th-outside diameter;

FIG. 13 is a drawing illustrating an example of an imaging system;

FIG. 14 is a drawing illustrating a working example of
5 an image processing unit of the inspection apparatus for the handrail of passenger conveyor of the invention;

FIG. 15 is a drawing illustrating a first example of the processing by the SC detection part of the inspection apparatus for the handrail of passenger conveyor of the invention;

10 FIGS. 16A to 16D are drawings illustrating an example of contrast compensation by the inspection apparatus for the handrail of passenger conveyor of the invention;

FIGS. 17A and 17B are drawings illustrating an example of detection of a temporary segment of steel cord by the
15 inspection apparatus for the handrail of passenger conveyor of the invention;

FIGS. 18A to 18D are drawings illustrating the processing of coupling temporary segments of a steel cord by the inspection apparatus for the handrail of passenger conveyor of the
20 invention;

FIG. 19 is a drawing illustrating a second example of processing by the SC detection part of the inspection apparatus for the handrail of passenger conveyor of the invention;

FIG. 20A is a drawing illustrating an example of the
25 collation method for an SC model and detected steel cords in

the inspection apparatus for the handrail of passenger conveyor of the invention;

FIG. 20B is a drawing illustrating an example of the collation method for an SC model and detected steel cords in the inspection apparatus for the handrail of passenger conveyor of the invention;

FIG. 20C is a drawing illustrating a distance table used in an example of the collation method for an SC model and detected steel cords in the inspection apparatus for the handrail of passenger conveyor of the invention;

FIG. 21 is a drawing illustrating a flow of processing by the SC model holding part and an SC trace/segment feature detection part of the inspection apparatus for the handrail of passenger conveyor of the invention;

FIG. 22 is a drawing illustrating a detection method for a segment feature "lack of steel cord" in the inspection apparatus for the handrail of passenger conveyor of the invention;

FIG. 23 is a drawing illustrating a detection method for a segment feature "contact between steel cords" in the inspection apparatus for the handrail of passenger conveyor of the invention;

FIG. 24 is a drawing illustrating a detection method for a segment feature "entangled steel cords" in the inspection apparatus for the handrail of passenger conveyor of the

invention;

FIG. 25 is a drawing illustrating an example of "individualized wire" in the inspection apparatus for the handrail of passenger conveyor of the invention;

5 FIG. 26 is a drawing explaining an example of a quantity judgment condition in the inspection apparatus for the handrail of passenger conveyor of the invention;

FIG. 27 is a drawing explaining a brightness measurement method used when a brightness threshold value Bth is unfixed;

10 FIG. 28 is a drawing illustrating a second working example of an image processing unit of an inspection apparatus for the handrail of passenger conveyor;

FIGS. 29A to 29C are drawings illustrating an example of an SC detection log table and an SC model log table;

15 FIGS. 30A to 30C are drawings illustrating another example of an SC detection log table and an SC model log table;

FIG. 31 is a drawing illustrating a method for implementing bidirectional trace;

20 FIG. 32 is a drawing illustrating a flow of processing by the image processing unit of the inspection apparatus for the handrail of passenger conveyor of the invention when bidirectional trace is carried out;

FIG. 33 is a drawing illustrating a flow of processing by the image processing unit of the inspection apparatus for
25 the handrail of passenger conveyors of the invention; and

FIG. 34 is a drawing illustrating an imaging system for detecting a wire by visible light.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

5 In the present invention, an object to be inspected is a continuous member including a steel cord used in a transport mechanism. As favorable examples of the continuous member of the transport mechanism, they include a handrail of passenger conveyor such an escalator, a moving sidewalk, and the like.
10 A bare wire rope used for elevator may be included in the continuous member of the transport mechanism.

 The invention includes an imaging unit of applying X-rays or visible light to form a projected image of the steel cord. When the object to be imaged is the steel cord of the handrail
15 for passenger conveyor, it is desirable to use an imaging unit using X-rays because the steel cord of the handrail is covered with an outer covering of a decorative rubber. Contrarily, when the object to be imaged is a bare wire rope (steel cord) for an elevator, desirable is an imaging unit using visible
20 light.

 The image processing unit carries out image processing of, for example, receiving the projected image from the imaging unit, and upon including a line segment thinner than each normal steel cord and higher in brightness than the normal steel cord
25 in the projected image, extracting the line segment as a

temporary segment of the steel cord having "individualized wire".
As a preferable example, the imaging unit is configured to,
for example, upon the steel cord having a normal outside diameter,
form an umbra of the steel cord, contrarily upon the steel cord
5 coming undone, form a thin penumbra. The image processing unit
is configured to previously set a brightness range taken as
a criterion for penumbra and extract line segments equivalent
to the "individualized wire" based on this criterion.

(Visualization and Pick-up of X-ray Image)

10 This embodiment judges deterioration of the steel cord
by processing to detect "individualized wire" of the steel cord
from the image obtained by shooting the handrail of the passenger
conveyor with X-rays. At this time, a criterion of detection
for "individualized wire" of the steel cord is whether or not
15 a feature of a line segment to be "individualized wire" lasts
for a predetermined length or longer in the direction of the
length of the handrail. Upon lasting for a predetermined length
or longer, "individualized wire" is detected. By utilizing
such detected feature of "individualized wire", the quality
20 of the handrail is evaluated, for example, in two levels of
no good state with damage and a good state with normal, or in
three or more levels of no good state with serious damage, a
caution state with light damage, and a good state with normal.

In this embodiment, image processing is carried out by
25 visualizing the steel cord built in the handrail of each

passenger conveyor by X-ray shooting. For example, the X-ray shooting is carried out for the handrail with built-in steel cords placed between an X-ray tube that applies X-rays and a scintillator that is a screen for visualizing an X-ray image in an environment with all outside light shut off. The scintillator is a sheet of paper or resin having several hundreds of μm or so in thickness with fluorescent material applied thereto, and emits light while it is irradiated with X-rays. In the scintillator, light emission with high brightness appears at a portion where a large dose of X-rays are irradiated without being blocked by the built-in steel cord; contrarily, non-light emission appears at an area where X-rays are not irradiated by being blocked with the built-in steel cord because of absorption of the X-rays into the steel cord or reflection of the E-ray on the steel cord. In actuality, however, some X-rays are diffusely reflected and thereby applied to even a part of the area where X-rays are blocked by the steel cord resulting in the scintillator emitting slight light with low brightness at such a part. For this reason, a relatively brightness distribution since is generated as a silhouette of the steel cord, the silhouette can be shot with a camera.

(Description of Wire)

The "individualized wire" cited here refers to a state where stranding of wires constituting the steel cord comes undone, so that at least part of the stranded wires individually exits

separately from others, wherein each wire is designated as an individualized wire. The outside diameter of each wire is approximately $1/5$ to $1/10$ of the outside diameter of each normal steel cord. Upon the outside diameter of each wire being 0.18 mm or so, for example, the outside diameter of the steel cord formed by stranding together these wires is 1.5 mm or so to 1.8 mm or so.

(Disclosure of Wire)

A physical measure for discriminating an ordinary steel cord and a wire from each other is their outside diameters. The outside diameter of the ordinary steel cord is 1.5 to 1.8 mm while the outside diameter of the wire is within the range of 0.15 to 0.3 mm. However, even when an image is shot with an optical lens system within the visible light range, it is difficult to obtain so clear an image that the outside diameter can be measured because of fluctuation in the distance between the camera and the wire. On the other hand, when shooting wires in the steel cord built in the handrail, in order to clearly take an image of very thin wires, it is necessary to apply a dose of strong X-rays from so small an aperture as less than 0.1 mm. However, since the output of X-rays is limited because of cooling, safety, and cost, the required size of an aperture for outgoing X-rays is 0.7 mm or so. So, it is necessary to carry out shooting through an X-ray exit aperture having a certain size, and thereby automatically detection of

"individualized wire" is carried out for the wire smaller in outside diameter than the size of the X-ray exit aperture.

As described later with reference to drawings, when shooting a steel cord with X-rays applied through the aperture having a certain size, in the scintillator, an umbra with a dark shadow is generated at an area where the X-rays are not irradiated by being completely blocked with the steel cord. In addition, the X-ray exit aperture since has a certain size, a part of the X-rays is not completely blocked with the steel cord resulting in a penumbra around the umbra. The penumbra is a shadow brighter than the umbra. The outside diameter of the wire since is smaller than the size of the X-ray exit aperture, the wire cannot form an umbra and its image is formed by only a penumbra. Therefore, when detecting an object comprised of only a penumbra, the object since is unlike an ordinarily steel cord having an umbra, it is possible to detect the wire from the penumbra in even an X-ray imaging system having an X-ray exit aperture larger than each wire. This method for detection of any wire as thin wire from the steel cord is applied not only to an X-ray imaging system but also a visible light projection imaging system. In the visible light projection imaging system, when radially projecting visible light from a light source having a finite size resulting in an object forming only a penumbra, it also is possible to detect any wire of a rope used for elevator or any wire of a rope used for crane

by the penumbra.

(Configuration Example of Inspection Apparatus)

In the description of this embodiment, a configuration of the inspection apparatus for the handrail of passenger conveyor will be presented as an example of an inspection apparatus for a continuous member for transport mechanism. This inspection apparatus can be configured, for example, as described below.

(1) The inspection apparatus is comprised of: an X-ray imaging unit of shooting a handrail of a passenger conveyor with X-rays; and an image processing unit of processing an image obtained by the X-ray imaging unit to detect "individualized wire" of a steel cord built in the handrail. Upon the "individualized wire" portion of the steel cord lasting for a predetermined length (first predetermined length) or longer in a direction of the length of the handrail, the image processing unit judges the quality of the handrail as no good state with serious damage.

(2) In relation to the above-mentioned configuration (1), upon the processing part detecting "individualized wire" portion of the steel cord and the "individualized wire" portion lasting within a certain range shorter than the above-mentioned predetermined length (first predetermined length) but equal to or longer than another predetermined length (second predetermined length), which is shorter than the above-mentioned predetermined length (first predetermined)

in the direction of the length of the handrail, the image processing unit judges the quality of the handrail as a caution state with light damage.

(3) In relation to Section (2), upon the processing part
5 detecting "individualized wire" portion of the steel cord and the "individualized wire" portion of the steel cord shorter than the above-mentioned certain range (second predetermined length), the image processing unit judges the quality of the handrail as a good state with normal.

10 In a maintenance method for passenger conveyor in this embodiment, the quality of each handrail is judged by the same judgment method as in the image processing unit described (1) to (3). Upon the quality judgment of the handrail being judged as no good state with serious damage, the handrail is repaired,
15 replaced, or replaced after repair. Upon the quality judgment of the handrail being judged as a caution state with light damage, the handrail is inspected again in a cycle shorter than an ordinary inspection cycle.

The above-mentioned configuration is just an example and
20 it can be appropriately modified without departing from the technical idea of the invention.

(Description of Working Examples)

Hereafter, description will be given to working examples of the invention with reference to drawings. In each drawing
25 and each working example, the same or similar constituent

elements will be marked with the same reference numerals and the duplicate description thereof will be omitted.

In the description of Working Example 1, as an example of an inspection apparatus for continuous member used for a transport mechanism, described is an inspection apparatus for handrail of a passenger conveyor capable of automatically diagnosing the stage of deterioration of a handrail.

(Example of Configuration for Imaging and Setup)

FIG. 4A illustrates an example of a configuration of the inspection apparatus for handrail of the passenger conveyor in this working example in state where the inspection apparatus is set on the handrail during inspection. The inspection apparatus is comprised of an X-ray imaging unit 1 and an image processing unit 2. The image processing unit 2 can be comprised of, for example, a personal computer. An encoder 3 is added as required.

The X-ray imaging unit 1 is comprised of an X-ray tube 5, a scintillator 6, and a camera 7. In the X-ray imaging unit, the X-ray tube 5 and the scintillator 6 is arranged on opposite sides of a handrail 4 to shoot a part of the handrail 4 and output the image to the image processing unit. That is, X-rays are applied radially from the X-ray tube 5 to penetrate the handrail 4, and irradiated onto the scintillator 6. The scintillator 6 is a fluorescent screen capable of generating fluorescence upon irradiation with X-rays, and the fluorescence

has brightness corresponding to a level of irradiation of the X-rays. The handrail 4 has steel cords therein, and a silhouette image is formed on the scintillator 6 in accordance with X-ray transmittance of members of the handrail. The image on the scintillator 6 is taken into the camera 7. The X-ray imaging unit 1 is shielded from external light, so it can efficiently take in only a radiographic image formed by light emission on the scintillator 6. The camera 7 is connected to the image processing unit 2 and the images are taken as electronic data into the image processing unit 2.

A lead glass 8 is placed between the scintillator 6 and the camera 7 to prevent X-rays applied by the X-ray tube 5 from damaging the camera 7. The lead glass 8 absorbs electromagnetic waves having an X-ray wavelength and allows electromagnetic waves having a wavelength band of visible light to penetrate, wherein the visible light can make light emission on the scintillator 6 and permits shooting of the camera 7. The lead glass 8 prevents X-rays from penetrating the camera 7 and allows only light derived from light emission by the scintillator 6 to reach up to the camera.

FIG. 4B illustrates an example in which the X-ray imaging unit is set on a handrail. The X-ray imaging unit 1 is set such that a part of the handrail 4 is placed therein. Upon the X-ray imaging unit 1 being set on the handrail, it has, for example, a mechanism capable of being separated into two

parts of a first part 1a comprising the camera 7, lead glass 8 and scintillator 6, and a second part 1b comprising the X-ray tube 5. So the handrail 4 is sandwiched by the two parts 1a and 1b at an upper side and a lower side, and two parts 1a and 1b are coupled together with a fastener. In the description, the passenger conveyor is exemplified by an escalator installed between an upper floor and a lower floor and having steps on which passengers get, and the X-ray imaging unit is set at a slope portion on the handrail. However, the set position of installation of the X-ray imaging unit is not limited to this arrangement. During shooting with X-rays, the X-ray imaging unit 1 and the handrail 4 are moved relative to each other. That is, the handrail 4 is moved while the X-ray imaging unit 1 is fixed, or the X-ray imaging unit 1 is moved while the handrail 4 is in a stop state. Thus a desired spot in the handrail can be shot with X-rays. Shooting with X-rays is continuously carried out as moving image shooting, and when holding the moving images in an image holding part such as a magnetic medium in the image processing unit 2 as a video file, for example, the MPEG format or the AVI format can be used.

FIG. 5 illustrates an example of a handrail X-ray image formed with the inspection apparatus for the handrail of passenger conveyor in this working example. A horizontal direction in the drawing is equivalent to the direction of the length of the handrail. The handrail is shot in such a relatively

narrow range as 5 mm to 20 mm in the direction of the length thereof. The reason for this is as described below. The X-ray inspection apparatus is required to be made compact so as to enable to be carried, so it is not provided with a cooling mechanism using oil. Therefore, the output of the X-ray tube is smaller than that of other equipment such as equipment for medical use. To effectively utilize the X-ray output, the X-ray tube is designed so as to apply X-rays within a shooting range of 5 mm to 20 mm or so in the direction of the length of the handrail and 50 mm or so in a direction orthogonal to the direction of the length of the handrail. However, this limitation on shooting range is merely imposed by compact design requirements. Therefore, the X-ray inspection apparatus for the handrail of passenger conveyor of the invention can also be materialized using an X-ray imaging mechanism having a wider range. Contrarily, even though the range in the direction of the length of the handrail is narrow, no problem arises because shooting is carried out while the X-ray imaging unit is moved in the direction of length.

As illustrated in FIG. 5, respective steel cords have low X-ray transmittance, so their images are formed as black line segments (dark areas). Areas (background) between the multiple steel cords arranged side by side are comprised of only rubber and they have relatively high X-ray transmittance, so their images are brightly formed (as bright areas). In this

example, the rubber portions at the both edge-side areas (upper and lower sides of the drawing: FIG.5) of the handrail since has relatively thicker thickness and has relatively lower transmittance, their image are formed as dark areas. The image
5 in this example has 18 lengths of the steel cords, which will be designated as 01-cord, 02-cord, ..., 18-cord from top to bottom of the drawing for the sake of convenience.

A brightness distribution on the left side of Fig. 5 represents the brightness distribution on a line in a direction
10 crossing the handrail at a right angle to the length of the handrail at the point indicated by arrow 9 (such a direction crossing the handrail at the right angle to the length of the handrail is a vertical direction in the drawing and will be hereafter referred to as a transverse direction or a direction
15 orthogonal to the direction of the length of the handrail). Each steel cord is equivalent to a valley in the brightness distribution. The edge-side thick rubber portions have relatively lower brightness which is also lower in contrast to the umbra of the steel cord than that of a central portion
20 of the handrail.

A single image shot by shot in the imaging unit although is within the range of 5 mm to 20 mm in the direction of the length of the handrail, it is possible to take a continuous image of the entire handrail extended to several tens of meters
25 as moving images by moving the X-ray imaging unit or the handrail

at a constant speed. It is desirable that during shooting, the X-ray imaging unit or the handrail should be moved at a constant speed. However, even when it is moved at non-steady-state speed, the encoder 3 can be used to compensate the images. The encoder 3 is fixed on the X-ray imaging unit 1 and measures the relative movement between the imaging unit 1 and the handrail 4, and outputs a signal of the movement to the image processing unit. The image processing unit 2 acquires an image from the moving images obtained at the X-ray imaging unit 1 based on the distance information from the encoder 3 each time the distance reaches a certain value. This makes it possible to simulatively obtain the moving images of the handrail 4 moving at a constant speed.

(Examples of Good State with Normal and No Good State with damage)

FIG. 6 is a conceptual rendering assuming an X-ray image of a handrail in a good state with normal. The direction of the length of the handrails is represented in a vertical direction of the drawing sheet for the sake of visualization. The areas of the steel cords are represented as dark areas (in black). In this conceptual rendering, the section 10 is a section where there is a seam portion of the steel cord. The seam portion is a slightly large gap between line elements of the steel cord, and brightly appears just like the areas between steel cords. Each steel cord slightly meanders. The steel cord of each handrail since has the above-mentioned discontinuity

as the gap due to the seam and meandering in a normal state, it is difficult to judge the deterioration of the steel cord from features of discontinuity and meandering.

FIG. 7A is a conceptual rendering of an X-ray image of
 5 a handrail involving "individualized wire" (coming
 undone-steel cord) in an initial stage of the deterioration.
 As illustrated in Fig.7, there since is the above-mentioned
 discontinuity due to the seam in any steel cord, even though
 there is a slightly large gap in the image, the handrail should
 10 not be judged to be deteriorated from such a gap. The handrail
 must be judged to be deteriorated upon detection of
 "individualized wire" having occurred in this gap portion. FIG.
 7B illustrates an individualized wire portion in an enlarged
 manner and FIG. 7C represents the individualized wire portion
 15 as a simple schematic diagram to explain a position of
 corresponding wire. The line segment 11 is an image of
 "individualized wire" of the steel cord.

(Imaging System)

FIG. 8 illustrates an example of the imaging system of
 20 the inspection apparatus for handrail of the passenger conveyor
 in this working example.

FIG. 8 illustrates a positional relation between the X-ray
 exit 12 of the X-ray tube 5, the steel cord 15 (one of the multiple
 steel cords) built in the handrail, and the scintillator 6.
 25 The X-rays are applied from an upper part to a lower part of

the drawing and a direction orthogonal to the plane of the drawing is equivalent to the direction of the length of the handrail and the steel cord. A steel cord 15 having a normal outside diameter (ordinary steel cord 15) is represented by a circle of a solid line marked with a reference numeral 15 in a cross section of the steel cord. A steel cord 16 having an outside diameter thinner than that of the normal state is represented by a circle of a solid line marked with a reference numeral 16 in a cross section of the steel cord. An arrow 13 with a broken line represents a range of an X-ray application. Two line segments 17 are drawn from both ends of the X-ray exit 12 toward an arbitrary point within an X-ray irradiation range on the surface of the scintillator 6. A broken line 4a represents a center level within a range where a group of the steel cord models exists substantially side by side. A circle 14 represented by a broken line is located such that its center is coincident with a position of the broken line 4a and the two line segments 17 are tangent to the circle 14. In the description of the X-ray inspection apparatus for the handrail of passenger conveyor of the invention, it will be defined that the normal steel cord is larger in outside diameter than the broken line circle 14 and that an element wire resulting from "individualized wire" is smaller in outside diameter than the broken line circle 14. Hereafter, the outside diameter of the broken line circle 14 may be referred to as borderline outside

diameter 14 in some cases.

FIG. 9 illustrates a brightness distribution of an image formed by a normal steel cord in the imaging system in FIG. 8. An ordinary steel cord 15 located at the position of the broken line 4a absorbs or reflects part of X-rays from the X-ray exit 12 and thereby forms an image (projected image) as a silhouette on the scintillator 6. Two line segments 18 of solid line and two line segments 19 of broken line are drawn as tangential lines to the steel cord 15 from two ends of the X-ray exit 12 to the scintillator 6. Each of two areas 20 (hatched areas) formed on the scintillator 6 by the line segment 18 and the line segment 19 drawn from different ends of the X-ray exit 12, is a projected area where the steel cord 15 partly blocks the applied X-rays. Namely, when the X-ray exit 12 is viewed from the scintillator 6 at any position in the projected areas 20, part of the X-ray exit 12 is hidden behind the steel cord 15. A light shadow designated as penumbra is formed at the areas 20 where the X-ray exit 12 is partly hidden behind the steel cord as mentioned above. That is, the areas 20 are areas where the steel cord 15 forms the penumbra. Areas 21 (dot-shaded areas) located outside the two line segments 19 are areas where the X-ray exit 12 is not hidden behind the steel cord 15 at all. Area 22 positioned between the two areas 20 is an area where the X-ray exit 12 is hidden by the steel cord 15 completely. A dark shadow designated as umbra is formed at the area 22 where

the X-ray exit 12 is hidden completely behind the steel cord 15 as mentioned above. That is, the area 22 is an area where the steel cord 15 forms the umbra. As the result of the umbra and penumbra being formed, the scintillator 6 delivers high
5 brightness in the areas 21 and low brightness in the area 22. The brightness of each area 20 is gradually lowered with going from one side in contact with the area 21 to another side in contact with the area 22 because the part of the X-ray exit 12 hidden behind the steel cord 15 is gradually increased in
10 its area with going from one side in contact with the area 21 to another side in contact with the area 22.

The X-ray images contain much random noise, so it is necessary to add smoothing filter processing to original images. The brightness distribution of the scintillator 6 obtained after
15 the smoothing filter processing is added, is represented by a curve 23 in FIG. 9. In the brightness distribution 23, a vertical axis represents brightness and a horizontal axis represents places on the scintillator 6.

X-rays applied from the X-ray exit 12 and having arrived at
20 the scintillator 6 since is gradually weakened with going near to a peripheral portion of the X-ray exit 12, to be more accurate, the brightness distribution 23 is somewhat low at a portion on the scintillator 6 corresponding to the peripheral portion.

FIG. 10 illustrates a brightness distribution of an image
25 formed by a thin steel cord with "individualized wire" in the

imaging system in FIG. 8. The steel cord 16 thinner than normal located at the position of the broken line 4a absorbs or reflects part of X-rays from the X-ray exit 12 and thereby forms a projected image as a silhouette on the scintillator 6. Two line segments 18 and two line segments 19 of broken line are drawn as tangential lines to the steel cord 16 from two ends of the X-ray exit 12 to the scintillator 6. The respective areas 21 (dot-shaded areas) located outside the two line segments 19 are areas wherein the X-ray exit 12 is not hidden behind the steel cord 15 at all. In the case of FIG. 10, there is no area where the X-ray exit 12 is hidden by the steel cord 15 completely on the scintillator 6 resulting in no umbra on the scintillator 6. Area 24 positioned between the two line segments 18 is an area where part of the X-ray exit 12 is hidden behind the steel cord 16 at a partially largest area when viewing from the scintillator 6. That is, the areas 24 are areas where the steel cord 15 forms the penumbra. However the area 24 is higher in brightness than the umbra area 22 in FIG. 9 because the X-ray exit 12 is not hidden completely by the steel cord 15 at the area 24 as mentioned above. Each of two areas 25 (hatched area) positioned between the line segment 18 and the line segment 19 drawn from an identical point at each one end of the X-ray exit 12, is an area where part of the X-ray exit 12 is hidden partly behind the steel cord 16 when viewing from the scintillator 6. Areas 21 (dot-shaded areas) located outside the two line segments

19 are areas where the X-ray exit 12 is not hidden behind the steel cord 15 at all, so the scintillator 6 generates high brightness at the areas 21. The area 24 and the areas 25 are projected areas where the steel cord 16 forms a penumbra on the scintillator 6. The brightness of each area 25 is gradually lowered with going from one side in contact with the area 21 to another side in contact with the area 24 because the part of the X-ray exit 12 hidden behind the steel cord 15 is gradually increased in its area with going from one side in contact with the area 21 to another side in contact with the area 24. The X-ray images contain much random noise, so it is necessary to add smoothing filter processing to original images. The brightness distribution of the scintillator 6 obtained after the smoothing filter processing is added, is represented by a curve 26 in FIG. 10. In the brightness distribution 26, a vertical axis represents brightness and a horizontal axis represents places on the scintillator 6. X-rays applied from the X-ray exit 12 and having arrived at the scintillator 6 since is gradually weakened with going near to a peripheral portion of the X-ray exit 12, to be more accurate, the brightness distribution 26 is somewhat low at a portion on the scintillator 6 corresponding to the peripheral portion.

FIG. 11 illustrates a brightness distribution of an image formed by a steel cord having the borderline outside diameter 14 in the imaging system in FIG. 8. The steel cord having the

borderline outside diameter 14 located at the position of the broken line 4a absorbs or reflects part of X-rays from the X-ray exit 12 and thereby forms a projected image as a silhouette on the scintillator 6.

5 Two line segments 18 and two line segments 19 of broken line are drawn as tangential lines to the steel cord having the borderline outside diameter 14 from two ends of the X-ray exit 12 to the scintillator 6. The areas 21 (dot-shaded areas) located outside the line segments 19 are areas where the X-ray
10 exit 12 is not hidden behind the steel cord 15 at all. In the case of FIG. 11, the two line segments 18 intersect each other at a point on the scintillator 6. For this reason, when viewing from the scintillator, an area where the X-ray exit 12 is hidden completely behind the steel cord having the borderline outside
15 diameter 14 exists only at one point on the scintillator 6, so a substantial umbra in the sense that it has a certain range does not exist. Areas 21 (dot-shaded areas) located outside the two line segments 19 are areas where the X-ray exit 12 is not hidden behind the steel cord 15 at all, so the scintillator
20 6 generates high brightness at the areas 21. An area 25 (hatched area) positioned inside the two line segment 19 is an area where part of the X-ray exit 12 is hidden partly behind the steel cord having the borderline outside diameter 14 when viewing from the scintillator 6. The area 25 is projected area
25 where the steel cord having the borderline outside diameter

14 forms a penumbra on the scintillator 6. Bth-Dash is taken as the minimum brightness value in this area inside the two line segments 19. In this case, a brightness distribution 27 draws a curve extended from background brightness Bbak with high brightness to minimum brightness value Bth-Dash. The X-ray images contain much random noise, so it is necessary to add smoothing filter processing to original images. The brightness distribution of the scintillator 6 obtained after the smoothing filter processing is added, is represented by a curve 27 in FIG. 11. In the brightness distribution 27, a vertical axis represents brightness and a horizontal axis represents places on the scintillator 6. X-rays applied from the X-ray exit 12 and having arrived at the scintillator 6 since is gradually weakened with going near to a peripheral portion of the X-ray exit 12, to be more accurate, the brightness distribution 27 is somewhat low at a portion on the scintillator 6 corresponding to the peripheral portion.

In terms of drawing, there is only one point at which the brightness is at the same level of darkness as an umbra on the scintillator 6. In actuality, however, Bth-Dash takes a higher value than Bmin by carrying out discretization with pixels having a finite spatial size and smoothing between adjacent pixels to remove the above-mentioned random noise. The half value width of the brightness distribution 27, that is, the width between points 27a, 27b at which the brightness distribution

27 crosses an intermediate brightness between B_{bak} and B_{th_Dash} , is taken as the threshold value W_{th_Dash} of the thickness of the steel cord. W_{th_Dash} can be used as the brightness threshold value to discriminate an ordinary steel cord and an elemental wire from each other. W_{th_Dash} although can be used as the brightness threshold value as mentioned above, in place of it, in order to emphasize a difference in brightness between a steel cord with an ordinary outside diameter and a wire, as illustrated in FIG. 12, the minimum value of the brightness value of an image obtained by a steel cord having the th outside diameter (threshold outside diameter) 14a, which is slightly smaller than the borderline outside diameter, is taken as the threshold value B_{th} .

FIG. 12 illustrates a brightness distribution of an image formed by a steel cord having the outside diameter (th outside diameter 14a), which is smaller than the borderline outside diameter 14 described with reference to FIG. 11 and larger than a wire ("individualized wire") to be detected in the imaging system in FIG. 8. The steel cord having the outside diameter 14a located at the position of the broken line 4a absorbs or reflects part of X-rays from the X-ray exit 12 and thereby forms a projected image as a silhouette on the scintillator 6. Two line segments 18 and two line segments 19 of broken line are drawn as tangential lines to the steel cord having the th outside diameter 14a from two ends of the X-ray exit 12 to the scintillator

6. The respective areas 21 (dot-shaded areas) located outside the two line segments 19 are areas wherein the X-ray exit 12 is not hidden behind the steel cord having the t outside diameter 14a at all. The areas 25 and area 24 located inside the two line segments 19 are areas where part of the X-ray exit port 12 is hidden behind the steel cord having the t outside diameter 14a resulting in a penumbra on the scintillator 6. In the areas 24 positioned between two points at which the two line segments 18 intersect the scintillator 6, the minimum brightness is generated and it is taken as threshold value B_{th} . In this case, a brightness distribution 27α is similar to the brightness distribution 27 in FIG. 11. However, the minimum brightness value is higher than that of FIG 11. The half value width of the brightness distribution 27α , that is, the width between points 27a, 27b at which the brightness distribution 27α crosses the intermediate brightness between B_{bak} and B_{th} can be used as the threshold value W_{th} of the thickness of the steel cords. B_{th} can be used as the brightness threshold value to discriminate an ordinary steel cord and a wire from each other.

In the imaging system in FIG. 8 to FIG. 12, the position 4a of placement of the steel cords is located in a position relatively near the X-ray tube 5 for convenience of explanation. However, upon location of steel cords relatively near the scintillator 6 like a position 4b of placement of the steel cords in FIG. 13, it is possible to ensure a larger range of

the X-ray image. Furthermore, even in a case of ordinary steel cords having a diameter larger than the borderline outside diameter 14, or even in a case of a thin steel cord having "individualized wire" by coming undone-steel cord, the range of the areas 20, 22, 24, 25 is spatially compressed on the scintillator 6 resulting in compact of the range. As a result, the radiation range of an X-ray can be narrowed and thus it is also possible to reduce the difference in brightness with which the central part of X-ray irradiation is bright and the peripheral part is dark. It should be noted that when the position of placement of the steel cords is changed from 4a to 4b, the borderline outside diameter 14 for discriminating an ordinary steel cord and a thin steel cord from each other is also changed.

A steel cord having a desired outside diameter as a coming undone-steel cord and "individualized wire" can be detected by taking the following procedure of: specifying an outside diameter of the steel cord to be determined as ordinary and that of a thin steel cord to be detected as an elemental wire; specifying a borderline outside diameter 14 or a th outside diameter 14a based thereon; and adjusting the size of the X-ray exit 12, and a positional relationship between the scintillator 6 and the position of placement of the steel cord.

As described above, description has been given with reference to FIG. 8 to FIG. 13 of: specifying the size of the

X-ray exit 12 and the positional relationship between the scintillator 6 and the position of placement of the steel cord; specifying a borderline outside diameter 14 or a th outside diameter 14a as a borderline of judgment as to "individualized wire"; and based on the above-mentioned specification, forming a projection of dark shadow designated as umbra when an object having been detected is a normal steel cord thicker than the borderline, or forming a projection of only a penumbra relatively high in brightness when an object having been detected is an elemental wire thinner than the borderline. With reference to FIG. 8 to FIG. 13, description has been given to cases where a thin steel cord 16 as an elemental wire is orthogonal to the plane of the drawings. Also when it is parallel to the plane of the drawings, an image of only a penumbra is obtained because of the size of the X-ray exit 12 and the positional relationship between the scintillator 6 and the position of placement of the steel cords. In the present invention, even when the cross section of the steel cord is not circular, it is possible to form an image of the umbra and the penumbra so clear that they can be easily discriminated from each other unless a diameter of the object takes a value approximate to the borderline outside diameter 14.

The vertical and horizontal sizes of an output surface of the X-ray source are preferable to be set such that an area of the output surface is larger than a cross-sectional area

of the wire in its outside diameter and further larger than a cross-sectional area of the steel cord in its borderline outside diameter to form the above-mentioned umbra of the steel cord and penumbra of the wire.

5 (Image processing unit of Handrail Inspection Apparatus)

FIG. 14 illustrates a working example of an image processing unit of the present invention and it can be embodied as, for example, the image processing unit 2. The image processing unit 2 is comprised of a frame acquisition part 28, a steel
10 cord detection part (hereafter, referred to as SC detection part) 29, a steel cord model holding part (hereafter, referred to as SC model holding part) 30, a steel cord trace/segment feature detection part (hereafter, referred to as SC trace/segment feature detection part) 31, a frame-by-frame
15 quality judgment part 32, a final judgment part 33, a display part 34, a command input part 35, and a control part 36. The SC trace/segment feature detection part 31 includes a wire detection part 311. Hereafter, the direction of the length of handrail will be referred to as "direction of length" and
20 the direction orthogonal thereto will be referred to as "orthogonal direction" for convenience of explanation.

The frame acquisition part 28 extracts one frame from the moving images of the handrail shot with the camera 7. Then it extracts a range containing steel cords therefrom and removes
25 random noise in image brightness and carries out contrast

compensation.

The SC detection part 29 detects each steel cord portion corresponding to independently existing each of the steel cords from the brightness distribution of this image and calculates
5 coordinates of each steel cord portion. The coordinates in the orthogonal direction to a barycenter of each steel cord, namely, the coordinates in the vertical direction in FIG. 5, is represented as the position of each steel cord in that frame.

The SC model holding part 30 updates and holds an SC model
10 group of the predetermined number of steel cord models. Regarding the SC model group, the updated and the held are the coordinates of each steel cord model in the orthogonal direction, brightness of the steel cord model, and information on brightness of the background area adjacent to the steel cord portion (the
15 update and held of the SC model group will be described later with reference to FIG. 29.) The steel cord models in the SC model group are named as cords 01, 02, ..., 18 as in FIG. 5.

The SC trace/segment feature detection part 31 compares representative coordinates of the detected steel cords to be
20 the output of the SC detection part 29 with the coordinates of the SC models held by the SC model holding part 30. Subsequently, the SC trace/segment feature detection part 31 brings coordinates of the respective detected steel cord and the SC models into correspondence with each other such that
25 the total difference (sum of differences) in coordinates both

of the detected steel cord and the SC models, which are corresponded in the predetermined number, becomes minimized. As the result of this processing, the correspondence between each of the steel cords detected in the current frame and the cord number of each of the steel cords, that is, cords 01, 02, ..., 18 in FIG. 5, is determined. Based on this correspondence, presence or absence of lack of steel cord, contact between steel cords, entangled steel cords, or "individualized wire" from steel cord in the current frame is detected, so the result of detection is held in a memory as a "frame-by-frame SC segment feature log". The representative coordinates of each steel cord is used as update information of the SC models at the SC model holding part 30. Each steel cord coordinate of the updated SC models is held as a "SC trace log in each trace" in a memory.

The frame-by-frame quality judgment part 32 refers to the "SC trace log in each trace" and confirms the presence or absence of a segment feature, that is, the lack of steel cord, contact between steel cords, entangled steel cords "individualized wire" of each steel cord found in the current frame, and determines over how many frames any of these features last when these features presents. Upon "individualized wire" lasting over the predetermined number of frames, the handrail is recorded as "no good state with serious damage" in frame-by-frame quality judgment logs. Upon "individualized wire" not lasting over the predetermined number of frames or

more, the handrail is recorded as "good state with normal". Upon "no good state with serious damage", the frames containing the segment feature causing "no good state with serious damage" are tracked back up to a starting point of the segment feature, so the record in each log from the frame at the starting point of the segment feature up to the frame at the time of judging the segment feature is revised to "no good state with serious damage". Thus, the "frame-by-frame quality judgment logs" are updated as mentioned above and held in the memory. In this case, when there are various segment features, the quality judgment can be carried out in multi-stages by using the result of logical multiplication of the presence or absence of various segment features, and then the quality judgment can be held as a log.

A final judgment part 33 refers to the total "frame-by-frame quality judgment logs", so the quality judgment of the overall handrail sample is carried out to output as a final judgment result.

The command input part 35 is implemented by a publicly known input device such as a keyboard and a mouse. The start and stop of processing by the image processing unit 2 can be controlled therefrom through the control part 36.

For the display part 34, a publicly known graphical user interface such as a display of PC can be used. On the display part 34, the quality judgment result outputted by the final

judgment part 33 can be displayed together with an image from the camera 7.

To alert maintenance service men using the handrail inspection apparatus of the invention, the image processing unit 2 of the invention can be configured so as to finish its own processing by inputting to the command input part 35 the same result as the result outputted by the final judgment part 33. Up to this point, description has been given to the configuration of the image processing unit 2.

10 (Frame Acquisition Part)

The frame acquisition part 28 sequentially takes frames out of acquired moving images and processes them. This processing may be carried out online or may be carried out offline. That is, in the case of online, each time the frame acquisition part receives a frame from the camera 7, the processing may be sequentially carried out, or in the case of offline, after temporarily storing the entire area of the handrail 4 to be inspected as a video file into a magnetic storage device, the processing may be carried out by reading out a frame sequentially from the magnetic storage device. It may be better to adopt the offline processing since images can be processed without imposing an excessive load on the image processing unit 2.

Upon the X-ray imaging unit 1 or a handrail 4 moving at non-steady-state speed and online processing being carried out based on distance information from the encoder 3, the frame

acquisition part 27 carries out processing of acquiring a frame in accordance with the output of the encoder 3 each time the handrail 4 is moved by a predetermined distance, for example, of 5 mm to 20 mm, and then processing the acquired frame. On the other hand, upon offline processing, for example, the frame acquisition part 27 acquires a frame in accordance with the output of the encoder 3 each time the handrail 4 is moved by a predetermined distance, for example, between 5 mm to 20 mm, and then makes a sampling video file sampled from the acquired frames and temporarily stores the thinned-out video file in a magnetic storage device. The video file made with such a configuration provides moving images of a handrail moving at a constant speed. The frame acquisition part 28 can read these moving images and acquire and process frames one by one. When the offline processing is carried out, it is unnecessary to provide the frame acquisition part 28 with a function of storing acquired moving images as a video file and moving images may be separately generated by moving image generating software.

Description will be given to the relation between a traveling speed of the handrail 4, a width of a range of the handrail X-ray image in the direction of the length of the handrail illustrated in FIG. 5, and the moving image frame rate of the camera 7. When a frame rate of the camera 7 is N frames per second, a time interval each between frames outputted from the camera 7 is $1/N$ seconds. When the traveling speed of the

handrail 4 is L millimeters per second, the handrail is moved by L/N millimeters while the camera 7 acquires one frame. Therefore, provided that the shutter of the camera 7 is kept in opening, upon the length of the range in the direction of the length of the handrail 4 being larger than L/N millimeters, all the image information of the handrail 4 is contained in the above-mentioned video file.

For example, provided that the frame rate of the camera 7 is 30 frames per second and the traveling speed of the handrail 4 is 500 millimeters per second, the movement measured while one frame is acquired is $500/30 \approx 16.7$ millimeters. Therefore, when the length of the range of the handrail X-ray image is equal to or longer than 17 millimeters, all the image information of the handrail 4 is contained in the above-mentioned video file.

When an interlace-type camera is used for the camera 7, each of 30 frames obtained every second contains two images to be an even field and an odd field different by approximately 16.7 milliseconds in acquisition time. When the two images are processed to be separated from each other, images can be obtained substantially with a frame rate of 60 frames per second. In this case, the movement measured while one frame is acquired is $500/60 \approx 8.3333$ millimeters. Therefore, provided that the size of the handrail X-ray image in the direction of the length of the handrail, illustrated in FIG. 5, is equal to or larger

than 8.4 millimeters, all the image information of the handrail
4 is contained in the above-mentioned video file.

(SC Detection Part)

Description will be given to the SC detection part 29.

5 FIG. 15 illustrates a first example of processing by the SC
detection part and illustrates a flow of the processing. By
using an X-ray image from the frame acquisition part 28,
generated is a brightness distribution being projected in the
direction of the length of the handrail as illustrated in, for
10 example, FIG. 5 (S1). By using the projection, it is possible
to cancel out random noise in brightness associated with X-ray
photography and measure the trend of brightness responding to
each place in the handrail in accordance with differences in
the thickness of rubber. A contrast compensation curve is
15 generated from the projected profile obtained at Step S1 (S2).
Subsequently, an HR orthogonal direction line is established
at a left end in the direction of length in order to analyze
the brightness distribution of the X-ray image in the orthogonal
direction one line by one line from the left end to the right
20 end or every predetermined lines from the left end to the right
end (S3).

Thereafter, carried out is a loop handling in the direction
of the length of the handrail (abbreviated as HR in FIG. 15)
(S4), and thereby analyzing is carried out for the X-ray images
25 from the frame acquisition part 28 within a field of view of

the X-ray images. More specific description will be given. The acquired brightness distribution is subjected to smoothing and contrast compensation to generate a brightness distribution on the established line (S5) and a temporary segment of the steel cord on the established line is detected (S6). The temporary segment of the steel cord refers to pixels having a potential that can be equivalent to a portion of a steel cord. The processing of Step S6 will be described in detail later. In a first time-loop handling at Step S4, a processing of Step S7 is not carried out and skipped. For a second time-loop handling and subsequent time-loop handling, a coupling is carried out between a temporary segment of the steel cord detected in a previous loop handling and a temporary segment of the steel cord detected in the current loop handling (S7). Regarding how to coupling therebetween, it will be described later. A next line to be analyzed is established on a right side of the line on which analysis has been carried out in the current loop handling (S8). When the analysis is terminated to the right end of the X-ray image, a next proceeding is moved from the loop handling of Step S4 (S9).

When a length of those coupled temporary segments of the steel cord, which is detected in the loop handlings carried out repeatedly at Step S4, reaches a predetermined length, those temporary segments are determined as a steel cord. And then, in barycenter coordinates of an object obtained by coupling

those temporary segments of the steel cord, the coordinate in the orthogonal direction is taken as the representative coordinate of the relevant steel cord in the relevant frame (S10). At Step S10, the number of the determined steel cords and the coordinates in the orthogonal direction of the determined steel cords in the frame are outputted from the SC detection part 29 to the SC model holding part 30 and SC trace/segment feature detection part 31 and the processing at the SC detection part 29 is terminated.

Next, concrete description will be given of the processing of Step S5. FIGS. 16A to 16D illustrate an example of contrast compensation by the SC detection part 29. FIG. 16A illustrates a brightness distribution on some line in the orthogonal direction of a handrail X-ray image acquired by the frame acquisition part 28. An axis in the vertical direction in the drawing represents the coordinate in the handrail orthogonal direction and an axis on the left of the drawing represents brightness. The brightness distribution forms valleys in places corresponding to steel cords and peaks in places corresponding to areas respective between steel cords. In addition, there since are random noises caused from brightness associated with X-ray imaging, relatively small valleys and peaks due to those noises exist in the brightness distribution. It is low in brightness in proximity to the upper end and lower end on the drawing (FIG 16A) and this makes reduction of contrasts

respective between valleys and peaks. The brightness distribution is subjected to smoothing and contrast compensation (S5) to make visible the valleys and peaks resulting from steel cords.

5 FIG. 16B illustrates a smoothed bright distribution obtained by smoothing the brightness distribution in FIG. 16A. This smoothing can be implemented by, for example, a publicly known smoothing filter described in Non-patent Document 1. Random noises can be favorably removed by using a smoothing
10 filter of sufficiently large size to the extent that the valleys or peaks resulting from steel cords are not erased as mentioned above.

 Upon settings of imaging parameters such as lens of the camera 7, the number of pixels of a steel cord to be detected
15 in an image is substantially determined; therefore, it is possible to determine an appropriate size of a smoothing filter beforehand. The areas in proximity to the upper end and lower end sides of the drawing, which corresponds to vicinities of edges in the handrail, are low in brightness and contrast between
20 valleys and peaks, so the vicinities of edges are needed to carry out contrast compensation.

 FIG. 16C illustrates a projected brightness distribution in the direction of length obtained at Step S1. The broken line 37 is an envelope of the maximum value of the projected
25 brightness distribution in the direction of length. A first

difference of the brightness distribution is calculated and a vicinity of zero crossing of the first difference is obtained as multiple maximum values. Thereafter, a curve in contact with these maximum values can be obtained by, for example, Lagrange's polynominal approximation. Thus obtained broken line 37 is taken as $f(x)$ and, for example, the smoothed brightness distribution (FIG. 16B) is multiplied by $CONST/f(x)$ resulting in a brightness distribution with contract compensation (FIG. 16D). Here, x represents a coordinate in the orthogonal direction and $CONST$ represents a constant. When the brightness value or brightness distribution value of an image is between 0 and 255 inclusive, a value of 200 or so is appropriate for the constant. The broken line 37 that provides a value of $f(x)$ is used for division. Therefore, it is effective to carry out clipping to prevent the value from becoming too small, for example, a numeric value of 10 or below for the prevention of instability. The clipping cited here is processing in which, when a numeric value of 10 or below occurs, it is replaced with a numeric value 11 or the like greater than the lower limit. FIG. 16D is a brightness distribution obtained by subjecting the brightness distribution in FIG. 16B to contrast compensation. There are 18 steep valleys and they correspond to the 18 steel cords. When steep valleys can be formed as mentioned above, a place where zero crossing occurs upon this brightness distribution being subjected to the first difference, can be

taken as a temporary segment of the steel cord.

Next, concrete description will be given to the detection of temporary segments of the steel cord (SC) (S6) and the coupling of temporary segments of the steel cord (S7). FIGS. 17A and 17B illustrate an example of the detection of a temporary segment of the steel cord by the SC detection part 29 (S6). FIG. 17A illustrates a brightness distribution that underwent contrast compensation just like that in FIG. 16D; and FIG. 17B illustrates a first difference in the brightness distribution with contrast compensation being obtained by subjecting the brightness distribution of FIG. 17A to a first difference in the orthogonal direction. In the first difference, a subtraction value between a brightness value below a remarkable point and a brightness value thereabove is taken as the value of the remarkable point. It is necessary to properly adjust a distance (number of pixels) between above the remarkable point and below the remarkable point beforehand. As in the invention, when the outside diameter of a steel cord to be detected is substantially predetermined, the adjusted distance can be held as a fixed value. Also for a positive threshold value 38 and a negative threshold value 39, proper adjusted values can be fixed and held.

For example, portions corresponding to valleys 40 in the brightness distribution in FIG. 17A can be obtained by determining coordinates with the respective minimum values of

the brightness distribution in FIG. 17A. That is, each of the minimum values to be each valley 40 exists in a certain coordinate section in the orthogonal direction, wherein the certain coordinate section is equivalent to a section where the first difference value increases from a point 42 as a negative threshold 39 of FIG. 17B (first difference value in brightness distribution with contrast compensation) up to a point 41 as a positive threshold 38 of FIG. 17B. Therefore, by obtaining coordinates equivalent to the minimum value FIG. 17A in the certain coordinate section between these points 42 and 41 in the orthogonal direction of FIG. 17B, each valley 40 is determined. The steepness of the valley 40 is calculated from a distance in the orthogonal direction between a maximum value 43 and a minimum value 44 of the first difference, so that, when the calculated distance is equal to or smaller than a predetermined fixed value, the valley 40 is discriminated as a steep valley. The place discriminated as a steep valley as mentioned above is a position of detection of a temporary segment of the steel cord in the brightness distribution in FIG. 17A.

FIGS. 18A to 18D illustrate the processing of coupling temporary segments of the steel cord by the SC detection part 29 (S7). FIGS. 18A, 18B, 18C, and 18D are a part of an image to be processed by the SC detection part 29. Hatched areas 45 and 46 represent independently existing steel cords, a hatched area 47 represents two steel cords in contact with each other,

and a hatched area 48 represents a short steel cord. In these drawings, group 49 of broken lines extended in the vertical direction explicitly represents lines for brightness distribution analysis established at Steps S3 and S8. That is, each brightness distribution is analyzed along these lines and the temporary segment of the steel cord is defined in the valley portion.

In FIG. 18B, a white rectangle 50 located on the hatched area 45 represents one of temporary segments of the steel cord.

Although the other rectangles located on the hatched area 45 also represent temporary segments of the steel cord, they are not marked with a reference numeral for prevention of complication of the drawing. White rectangles located in the hatched areas 46 and 48 also represent temporary segments of the steel cord. In the hatched area 47, a steep valley is not formed in the brightness distribution because of contact between steel cords and a temporary segment of the steel cord cannot be established there. That a temporary segment of the steel cord cannot be established means that there is no steel cord independently existing in no contact with others.

FIG. 18C explicitly illustrates the operation of the loop processing of Step S4. More specific description will be given. The processing is progressed from the left end to the right end, that is, from line 49a, ..., line 49d for brightness distribution analysis. In FIG. 18C, a steel cord (SC)-temporary

segment having established already is represented by a white rectangle of solid line; and a SC- temporary segment not having been established yet but being established that the SC-temporary will be established after completion of the processing, is represented by a rectangle of broken line. At Step S7, a temporary segment of the steel cord established on the previous line and a temporary segment of the steel cord established on the current line are coupled together. At this time, such coupling is carried out for temporary segments of the steel cord shortest in distance therebetween. The distance cited here refers to a difference in the coordinate in the orthogonal direction between the temporary segments of the steel cord. Erroneous coupling can be prevented by presetting an upper limit for the distance within which temporary segments of the steel cord can be coupled together.

Solid lines 51, 52, and 53 in FIG. 18D explicitly illustrate the result of temporary segments of the steel cord coupled at Step S7. This indicates that there are independent long steel cords 51 and 52 and short steel cord 53 in the relevant frame.

Preset is a threshold value of length for determination of a steel cord. At Step S10, a result of temporary segment-coupling with a length equal to or longer than the threshold value of length, is detected as a steel cord. Contrarily, a result of temporary segment-coupling with a length less than the threshold value of length, is excluded from

determination of a steel cord. The size in the direction of length of each handrail X-ray image acquired by the frame acquisition part 28 is determined in advance of the inspection of handrail when the X-ray imaging unit 1 is designed, therefore, the above-mentioned threshold value of length also can be set in advance of the inspection.

In the above description, explanation has done about the example where smoothing and contrast compensation are carried out each time one line is analyzed in the HR processing loop at Step S4. Instead of that, as a processing flow in a second example of the processing by the SC detection part 29 and the processing flow illustrated in FIG. 19, the invention may adopt the processing of smoothing and contrast compensation being carried out as two-dimensional image processing (S11) and then brightness distribution analysis being carried out line by line. In FIG. 19, the processing of Steps S1 and S2 is the same as that described with reference to FIG. 15. At Step S11, a two-dimensional smoothing filter is applied in the handrail X-ray image acquired by the frame acquisition part 28 to cancel out brightness random noise associated with X-ray imaging. This smoothing can be implemented by the publicly known two-dimensional smoothing filter described in Non-patent Document 1. In contrast compensation, by using the contrast compensation curve $f(x)$ obtained at Step S2, the pixels in the X-ray image are multiplied by $CONST/f(x)$. When the pixel value

exceeds the upper limit of 255 or like at this time, carried out is clipping processing, such as replacing the pixel value with the upper limit value. At Step S11 in the processing described up to this point, an X-ray image that underwent
5 smoothing and contrast compensation is generated.

The processing of Steps S3 and S4 is the same as that described with reference to FIG. 15 and brightness distribution analysis is carried out from the left end to the right end of the X-ray image one line by one line or every predetermined
10 line. The brightness distribution obtained here is equal to the brightness distribution obtained at Step S5 in FIG. 15, that is, the brightness distribution in FIG. 16D. The subsequent processing of Steps S6 to S10 is the same as the processing in the processing flow described with reference to
15 FIG. 15.

(SC Model Holding Part)

FIGS. 20A to 20C illustrate a collation method for SC models and detected steel cords. Description will be given to the collation method carried out between the SC models and
20 the detected SCs respectively with reference to FIGS. 20A to 20C. The collation method is carried out through cooperation processing of the SC model holding part 30 and the SC trace/segment feature detection part 31.

To simplify the explanation, it will be assumed that the
25 number of the steel cords built in the handrail is originally

five. Thus the SC model is also comprised of five steel cords and they can be sequentially named 01-cord, 02-cord ,03-cord, 04-cord, and 05-cord from end to end.

It will be assumed that five steel cords are detected
5 at the SC detection part 29. In this case, the steel cords detected sequentially from one-side, are unconditionally brought into correspondence with the SC modes in SC model group in order of cord number (FIG. 20A). That is, the detected steel cords 54, 55, 56, 57, and 58 are respectively brought into
10 correspondence with 01-cord, 02-cord, 03-cord, 04-cord, and 05-cord in the SC models. As the result of this processing, the names of 01-cord to 05-cord are respectively determined for the detected steel cords. Each of the 01-05 cords in the SC models also has position information (coordinate), and the
15 coordinates of 01-05 cords in the SC models are updated with the coordinates of barycenter representing the positions of the detected steel cords having been brought into correspondence with SC models. White circle in the center of each detected steel cord in FIG. 20A explicitly indicates the position of
20 the respective barycenter.

FIG. 20B illustrates a case where the number of detected steel cords is three. This is equivalent to a case where two steel cords are in lack or in contact with each other or others, and they cannot be detected as two independent steel cords.
25 In this case, when applying a restraint condition that the order

of the SC model should not be changed, the detected steel cord
 59 can be brought into correspondence with 01-cord, 02-cord,
 and 03-cord in the SC models. If the detected steel cord 59
 is brought into correspondence with 04-cord, either the detected
 5 steel cord 60 or 61 is left out of correspondence. According
 to the similar restraint condition, the detected steel cord
 60 can be brought into correspondence with 02-cord, 03-cord,
 and 04-cord in the SC models and the detected steel cord 61
 can be brought into correspondence with 03-cord, 04-cord, and
 10 05-cord.

A distance table in FIG. 20C summarizes these conditions
 in a form of table. A column at the left end of the distance
 table indicates the cord names in the SC models. The first
 row at the upper end in the distance table indicates the steel
 15 cords detected in the current frame and they are entered from
 left to right in the ascending order of the magnitude of the
 detected coordinate. In this example, the detected steel cords
 59, 60, and 61 are sequentially entered from the left side to
 the right side. At this point of time, it is unknown which
 20 steel cord has been in lack and a name cannot be determined
 for the detected steel cord. In the distance table, an absolute
 value of difference between a coordinate in each SC model and
 a coordinate of its relevant detected steel cord is entered
 into each field where the row and the column intersect with
 25 each other. Asterisks marked in some fields of the distance

table represent impossible combinations of an SC model and a detected steel cord under the above-mentioned restraint condition. The other fields, that is, d11, d21, d31, d22, d32, d42, d33, d43, and d53 represent absolute values of differences between respective SC models and their relevant detected steel cords. The column at the right end of the distance table includes fields for entering any minimum coordinate difference which is a minimum value of coordinate difference between the SC model and the detected steel cord. The 01-cord and the 05-cord in SC models since respectively have only the values of d11 and d53, these values are entered into the corresponding fields as minimum values. In the other fields for minimum value, the respective minimum values in the corresponding rows of the distance table are entered thereinto. In the row of 02-cord, for example, either d21 or d22, which is smaller than the other, is entered. When they, for example, d21 and d22 are equal, both of their numeric values are entered thereinto.

In this example, the number of the SC models in the SC model group is five while the number of the detected steel cords is three. Therefore, undetected are any two steel cords. The two steel cords undetected are determined as follows. First of all, any two minimum values are sequentially selected in the descending order of magnitude from fields of the column at the right end of the distance table. Here selected as the undetected steel cords are steel cords corresponding to the

rows entering the above-two minimum values in the descending order of magnitude. When the row of 02-cord and the row of 03-cord are selected, for example, the 02-cord and the 03-cord are determined that they have undetected steel cords. As a result, the detected steel cord 59 is brought into correspondence with the 01-cord in the SC model group and it is determined as 01-cord. The detected steel cord 60 is brought into correspondence with the 04-cord in the SC model group and is determined as 04-cord. The detected steel cord 61 is brought into correspondence with the 05-cord in the SC model group and is determined as 05-cord.

As the result of the above-mentioned processing, the names of the detected steel cords are determined. Meanwhile, in SC models of the SC model group, the coordinate of the 01-cord is updated with the coordinate of the steel cord 59; the coordinate of the 04-cord is updated with the coordinate of the steel cord 60; and the 05-cord is updated with the coordinate of the steel cord 61. The 02 and 03-cords of SC models are updated with the coordinates respectively divided internally to 1:2 and 2:1 between the coordinates of the updated 01 and 04-cords of the SC models.

The processing described up to this point is carried out in accordance with the flow of processing in FIG. 21. FIG. 21 illustrates a flow of the processing by the SC model holding part 30 and the SC trace/segment feature detection part 31.

When the number of detected steel cords is equal to the number of the steel cords built in the handrail in design, it is determined that all the steel cords have been detected. Then the processing of Step S21 is carried out and this series of processing is terminated. At Step S21, the detected steel cords are brought in correspondence with their relevant SC models in the SC model group sequentially in the ascending order of magnitude of coordinates of the detected steel cords, and in the ascending order of magnitude of the numerals of the cord names of SC models respectively. Steel cord information in the SC models includes the coordinates of the respective SC models and the brightness of an original image, that is, the brightness at their coordinate position in a handrail X-ray image acquired by the frame acquisition part 28. This is equivalent to the brightness value of the corresponding steel cord portion. Further, brightness of places at a predetermined distance from each SC model, on both sides of the SC model, is held as background brightness. Here the predetermined distance is equivalent to a middle point between coordinates of adjacent SC models. At Step S21, these coordinates and brightness to be the steel cord information in the SC models are updated.

On the other hand, when the number of the detected steel cords is insufficient, the flow proceeds to the processing of P1 (S20). In the processing of P1, the distance table described

with reference to FIG. 20C is generated regarding the current SC model and the detected steel cords (S22). As described above, in accordance with the minimum coordinate difference, undetected steel cords are identified, and cord names are given to the detected steel cords (S23). The coordinates in the SC model are updated based on the coordinates of the detected steel cords (S24). At this time, the brightness is not updated.

Up to this point, description has been given to the trace of steel cords and the updating of SC models by the cooperation processing of the SC model holding part 30 and the SC trace/segment feature detection part 31. The trace of steel cords is carried out by the SC trace portion of the SC trace/segment feature detection part 31. The above description has not done a case where detected is a larger number of the steel cords than the number of the steel cords in design. It is because the smoothing processing and the like are sufficiently carried out at the SC detection part 29 to prevent a false steel cord from being detected and there is not such a case where a larger number of the steel cords are detected.

(Segment Feature Detection Method)

Next, description will be given of a method for detecting a segment feature related to deterioration of the steel cord carried out at the SC trace/segment feature detection part 31. This detection is carried out by the segment feature detecting portion of the SC trace/segment feature detection part 31. The

segment features are appearance features associated in deterioration found in the relevant frame and include missing (lack) of a steel cord, contact between steel cords, and the presence of a steel cord with "individualized wire". When contact has occurred not only in adjoining steel cords but also not adjoining steel cords together or in three or more steel cords together, they constitutes a feature of entangled steel cords.

FIG. 22 illustrates how the segment feature "lack of steel cord" is detected by the SC trace/segment feature detection part 31. In FIG. 22, rectangle 62 containing sixteen black horizontal stripes is a conceptual rendering of a handrail X-ray image. Sixteen black horizontal stripes represent sixteen independently existing steel cords and they are detected by the SC detection part 29. Each horizontally long rectangle surrounded by a broken line 63 represents a detected steel cord. Eighteen horizontal line segments 64 represent positions of the coordinates of the SC models in the SC model group held at the SC model holding part 30 and they are 01-cord, 02-cord, ..., and 18-cord from top. The sixteen detected steel cords 63 have already been given names through the above-mentioned cooperation processing of the SC model holding part 30 and the SC trace/segment feature detection part 31. In this example, the 09-cord and the 10-cord are undetected. Regarding coordinates of the undetected steel cords should being

originally, they can be known from the above-mentioned SC models, and they are equivalent to a portion encircled with the broken line 65.

Here, calculation is carried out for minimum brightness
5 in an area encircled with the broken line 65 in the X-ray image. Upon the calculated minimum brightness being larger than a predetermined threshold value, determined is carried out as lack of steel cord. The predetermined threshold value is obtained from an average value of the brightness of a SC model
10 and the background brightness of an area adjacent to the SC model. In the case of this example, the brightness of 09-cord and 10-cord in the SC model group is taken as the representative brightness of the SC models; the brightness at the middle point coordinate between the coordinates of the 09-cord and the 10-cord
15 is taken as the representative background brightness of the SC models; and the predetermined threshold are obtained by an average value of the representative steel cord brightness and the representative background brightness, wherein the threshold value is used for determining whether or not a steel
20 cord is in lack. As mentioned above, the brightness of 01-cord to 18-cord in the SC models and the background brightnesses of the areas therebetween are values updated in a frame in which all the steel cords are detected. When any steel cord lacks in a position where the steel cord should be independently
25 detected and the brightness of the position is higher than the

threshold value, it can be determined that any steel cord is in lack. Lack of a steel cord in the frame is detected by the processing described up to this point.

FIG. 23 illustrates how the segment feature "contact
 5 between steel cords" is detected at the SC trace/segment feature detection part 31. In FIG. 23, the rectangle 66 containing seventeen black horizontal stripes is a conceptual rendering of a handrail X-ray image. What is in an area of a broken line 69 is a steel cord having a thick appearance because of contact
 10 between steel cords. The other sixteen black horizontal stripes represent sixteen independently existing steel cords and they are detected by the SC detection part 29. Each horizontally long rectangle surrounded by a broken line 67 represents a detected steel cord. Regarding such a steel cord
 15 having a thick appearance as represented by the broken line 69, a steep valley does not occur in its brightness distribution as described above in relation to the SC detection part 29 and it cannot be detected. Eighteen horizontal line segments 68 represent the positions of the coordinates of the steel cords
 20 in the SC model held at the SC model holding part 30 and they are 01-cord, 02- cord, ..., and 18-cord from top. The sixteen detected steel cords 67 have already been given names through the above-mentioned cooperation processing of the SC model holding part 30 and the SC trace/segment feature detection part
 25 31. In this example, the 09-cord and the 10-cord are undetected.

Regarding coordinates of the undetected steel cords should be originally, they can be known from the above-mentioned SC models, and they are equivalent to an area encircled with the broken line 69.

5 Here calculation is carried out for minimum brightness in the area encircled with broken line 69 in the X-ray image. Upon the calculated minimum brightness being smaller than a predetermined threshold value, determined is carried out as contact of steel cords to each other. The predetermined
10 threshold value is obtained from an average value of the brightness of a SC model and the background brightness of an area adjacent to the SC model as mentioned above. In the case of this example, the 09-cord and the 10-cord in the SC model group since are undetected, it is determined that these
15 undetected steel cords are in contact with each other. When any steel cord lacks in a position where the steel cord should be independently detected and the brightness of the position is lower than the threshold, it can be determined that any steel cords are in contact with each other. Contact of the steel
20 cords in the frame is detected by the processing described up to this point.

FIG. 24 illustrates how the segment feature "entangled steel cords" is detected at the SC trace/segment feature detection part 31. In FIG. 24, the rectangle 70 containing
25 sixteen black horizontal stripes is a conceptual rendering of

a handrail X-ray image. What is in an area of a broken line 73 is a steel cord having a thick appearance because of entangled steel cords. The other fifteen black horizontal stripes represent fifteen independently existing steel cords and they are detected by the SC detection part 29. Each horizontally long rectangle surrounded by a broken line 71 represents a detected steel cord. Regarding such a steel cord having a thick appearance as represented by the broken line 73, a steep valley does not occur in its brightness distribution as described above and it cannot be detected. Eighteen horizontal line segments 72 represent the positions of the coordinates of the steel cords in the SC model held at the SC model holding part 30 and they are 01-cord, 02-cord, ..., and 18-cord from top. The fifteen detected steel cords 71 have already been given names through the above-mentioned cooperation processing of the SC model holding part 30 and the SC trace/segment feature detection part 31. In this example, the 08-cord, 09-cord, and 10-cord are undetected. Regarding coordinates of the undetected steel cords should being original, they can be known from the above-mentioned SC models, and they are equivalent to an area encircled with the broken line 73.

Here calculation is carried out for minimum brightness in the area encircled the broken line 73 in the X-ray image. Upon the calculated minimum brightness being smaller than a predetermined threshold value, determined is carried out as

contact of steel cords to each other. The predetermined threshold value is obtained from an average value of the brightness of a SC model and the background brightness of an area adjacent to the SC model as mentioned above. In the case of this example, the 08-cord, 09-cord, and 10-steel cord in the SC model group since are undetected, it is determined that these steel cords are in contact with each other. In this case, three or more steel cords are in contact with each other and thus any steel cords other than the adjoining steel cords are also in contact with each other; therefore, it is determined that entangled steel cords has occurred.

In the above-description, in order to determine the presence or absence of lack of steel cord, contact between steel cords, or entangled steel cords, it is needed to refer to the brightness of the area encircled by the broken line 65, the area encircled by the broken line 69, and the area encircled by the broken line 73. Therefore, the minimum brightness at these areas are used as the brightness to be referred. Instead of them, the used may be minimum brightness in the equivalent areas in a smoothed image acquired at the SC detection part 29. With this configuration, the X-ray photography is not influenced by variation in brightness.

(Wire Detection Method in Segment Feature Detection Method)

Next, description will be given to the wire detection part 311 for detecting a wire occurred as the result of

"individualized wire" featured in the SC trace/segment feature detection part 31, and description will be also about a wire detection method for detecting a wire caused by "individualized wire".

5 FIG. 25 is a conceptual rendering of a handrail X-ray image and illustrates an example in which "individualized wire" has occurred in some of the steel cords.

 In FIG. 25, black rectangles 74 to 77 represent typical examples of images of the steel cords having a normal outside
10 diameter. The hatched linear areas 78 and 79 represent examples of "individualized wire" (coming undone-steel cord) to be detected. The outside diameter of each wire is approximately 1/10 to 1/5 or so of the outside diameter of each normal (ordinary) steel cord. As described in relation to the imaging system
15 with reference to FIG. 8 to FIG. 12, the size of the X-ray exit 12 since is finite and is not zero, only a penumbra is formed by a wire having diameter smaller than the borderline outside diameter 14 or the th outside diameter 14a. Therefore, wire 78 and wire 79 to be detected are not only smaller in width
20 than the normal steel cords 74 to 77 but also higher in brightness than them. A direction of the length of any wire being individualized is not limited to the direction of the length of the handrail and can be every direction. The vicinity of each steel cord having a normal outside diameter forms a penumbra
25 and its brightness is close to that of the wire being

individualized. However, the position of a steel cord detected by the SC detection part 29 is equivalent to the valley portion in the above-mentioned brightness distribution for detection and is a portion equivalent to an umbra. Therefore, the
5 brightness of a steel cord (normal steel cord) having an ordinary outside diameter in a position detected by the SC detection part 29 is equal to the brightness of an umbra. That is, the brightness is B_{min} defined by the brightness distribution 23 in FIG. 9.

10 Here, description will be given to the brightnesses of images formed by an ordinary (normal) steel cord and a wire. As mentioned above, the ordinary steel cord forms a dark umbra, but the wire having a diameter smaller than the borderline outside diameter 14 forms an image of only a penumbra. The
15 absolute brightnesses of umbras and penumbras differ depending on sensitivity of the scintillator 6. They are varied on an image shot with the camera 7 by the sensitivity and gain adjustment of the camera. Therefore, after the X-ray tube 5, the scintillator 6, the steel cord placement position 4a, and
20 the size of the X-ray exit 12 are determined in the imaging system described with reference to FIG. 8 to FIG. 12, the gain of the camera 7 is determined. Thereafter, an ordinary steel cord is shot with the camera 7, and the brightness value of an umbra formed by the steel cord in a digital image is set to
25 B_{min} . When the brightness of one pixel is quantized to 0 to

255, it is desirable to adjust Bmin to 80 or below. It is desirable that the brightness Bbak of an area that is not an umbra or a penumbra, that is, a portion of the area 21 as background should be adjusted to 160 or above.

5 Subsequently, shooting with the camera 7 is carried out for an X-ray image of an object having the borderline outside diameter 14 or the th outside diameter (threshold outside diameter) 14a, so Bth is set for the minimum brightness in the penumbra formed by the borderline outside diameter 14 or the
10 th outside diameter 14a in a digital image as the shot X-ray image.

 Here, description will be given to an outside diameter of the steel cord having the borderline outside diameter 14 providing a boundary between an outside diameter of each normal
15 (ordinary) steel cord and an outside diameter of each wire. Regarding the steel cords and wires, when description is given to outside diameters of them on the images, it is convenient to describe such outside diameters in accordance with the number of pixels in the digital image. With the configuration
20 described with reference to FIG. 11 or FIG. 12, a brightness distribution 27 or 27 α is plotted from the X-ray tube 5, the scintillator 6, the steel cord placement position 4a, the size of the X-ray exit 12, and a steel cord having the borderline outside diameter 14 or the th outside diameter 14a. Use of
25 the th outside diameter 14a is preferable to use of the borderline

outside diameter 14. Hereafter, therefore, description will be given in the case of using the th outside diameter 14a with reference to FIG. 12. In the brightness distribution 27 α , a curve in the transitional section from the minimum brightness value Bth to the background brightness value Bbak, can be drawn by connecting both ends of the section by a straight line (Bbak is areas 21 that is neither an umbra nor penumbra). Then a borderline width Wth is determined from the difference between places 27a and 27b at which the brightness distribution 27 α crosses the intermediate value Bmd1 (for example, $Bmd1 = (Bth + Bbak) / 2$) between Bth and Bbak in the brightness distribution 27 α . The predetermined width determined based on the borderline width Wth is originally within a range between 1/10 mm and several millimeters. It can be divided by the pixel size per pixel when an image is picked up with the camera 7 to obtain a number of pixels. Hereafter, the borderline width Wth will refer to the number of pixels determined based on the th outside diameter 14a.

Based on the foregoing, FIG. 1 illustrates a flow of processing for detecting a wire represented by the wire 78 and the wire 79. In FIG. 1, the smoothing is carried out for an entire X-ray image obtained by the frame acquisition part 28 (S30) to remove random brightness variation noise characteristic of X-ray images. The smoothing can be implemented by, for example, a 3 $\times$ 3-pixel smoothing filter.

The smoothing is implemented by substituting an average value of eight nearby pixels adjoining to a pixel of interest in the vertical direction, horizontal direction, and diagonal directions for the brightness of the pixel of interest. The smoothing can also be implemented by such a publicly known smoothing filter as described in Non-patent Document 1 (Digital Image Processing, published by CG-ARTS Society (2006), pp. 106-110). To carry out a processing loop of Step S32 on the image having underwent the smoothing, the image processing unit 2 sets a pointer (scanning start point) for accessing pixel values at the upper left of the image (S31). The brightness value (pixel value) of the pixel of interest is compared with Bth which is the lower limit of the brightness value of a penumbra formed by a steel cord having the th outside diameter 14a (S34). When the brightness value (pixel value) is higher than Bth, a line segment detection processing described later is carried out (S35). This is because the brightness of the penumbra formed by a wire to be detected is higher than Bth as described above. Incidentally, when the borderline outside diameter 14 is used, Bth_Dash can be used as the value of Bth. It is determined whether or not the range of the image has been completely processed by the line segment detection processing of Step S35. When the processing is completed (YES), the flow comes out of the processing loop of Step S32 (S36). When the processing has not been completed yet, the pixel pointer is updated (S37)

until the line segment detection processing of Step S35 is finally completed over the processing range of the image. In the line segment detection processing of Step S35 described later, used is a processing kernel with a predetermined size, for example, 7×7 pixels. Attention should be paid to prevent the processing kernel from getting out of the processing range during the processing of Step S35. When the size of the relevant image is 640 pixels wide and 480 pixels long and the processing range is the entire image, for example, in the processing by the 7×7-pixel kernel, the pixel pointer is updated from the fourth pixel to the 637th pixel in the horizontal direction (S36, S37). In addition, in the vertical direction, the pixel pointer is updated from the fourth pixel (row) to the 477th pixel (row) (S36, S37). Subsequently the line segment analysis processing of Step S33 is carried out on the result of processing by the processing loop of Step S32 to detect a wire.

The line segment detection processing of Step S35 carries out a processing of detecting any line segment in all directions, upon the brightness of the line segment being equal to or higher than the penumbra brightness-lower limit threshold value B_{th} , and being equal to or lower than the intermediate brightness value B_{mdl} as a basis for borderline width W_{th} . All directions cited here may be eight nearby directions, that is, the horizontal direction, the diagonally upper left direction at 45°, the diagonally upper right direction at 45°, and the vertical

direction in each image. Or, they may be directions divided with a narrower pitch. In the case of eight nearby directions, for example, line segment detection filters a1, a2, a3, and a4 illustrated in FIG. 2 are sequentially applied to pick up
5 pixels meeting a predetermined condition. The results of applying the line detection filters are aggregated into a line segment aggregation image 80 (described later). It is assumed that all the pixels in the line segment aggregation image 80 have been cleared to zero prior to the line segment detection
10 processing of Step S35. In this example, used although is a 7×7-pixel filter, instead of it, 3×3-pixel, 5×5-pixel, 9×9-pixel, or the like can be selected in correspondence with the borderline width Wth. For example, the line segment detection filter a1 detects a penumbra extended in the horizontal
15 direction as indicated by reference code b1, and the base-point pixel m1 of the line segment detection filter a1 is aligned with the pixel of interest. That is, the brightness of the base-point pixel m1 becomes the brightness value of the pixel of interest. The brightness values of pixels equivalent to
20 ref11 and ref12, namely, for example, the brightness values of the third pixels above and below from the pixel of interest, are referred to the line segment detection. When the brightness of these upper and lower sides- referred pixels ref11 and ref
25 it is determined that a penumbra b1 extended in the horizontal

direction exists in the position of the pixel of interest. Then the predetermined pixel value of the line segment aggregation image 80 is set to, for example, 255 or other like so as to enable to identify the line segment in the horizontal direction.

5 Similarly, the base-point pixel m2 of the line segment detection filter a2 is aligned with the pixel of interest. When the brightness of the pixel of interest is lower than the pixel values corresponding to ref21 and ref22 on a diagonal line rising to right, it is determined that a penumbra b2 extended in the
10 upper left direction at 45° exists in the position of the pixel of interest. Then the predetermined pixel value of the line segment aggregation image 80 is set to, for example, 255 or other like so as to enable to identify to the line segment in the upper left direction at 45°.

15 Similarly, the base-point pixel m3 of the line segment detection filter a3 is aligned with the pixel of interest. When the brightness of the pixel of interest is lower than the pixel values corresponding to ref31 and ref32 on a diagonal line rising to left, it is determined that a penumbra b3 extended in the
20 upper right direction at 45° exists in the position of the pixel of interest. Then the predetermined pixel value of the line segment aggregation image 80 is set to, for example, 255 or other like so as to enable to identify to the line segment in the upper right direction at 45°.

25 Similarly, the base-point pixel m2 of the line segment

detection filter a4 is aligned with the pixel of interest. When the brightness of the pixel of interest is lower than the pixel values corresponding to ref41 and ref42, it is determined that a penumbra b4 extended in the vertical direction exists in the position of the pixel of interest. Then the predetermined pixel value of the line segment aggregation image 80 is set to, for example, 255 or other like so as to enable to identify to the line segment in the vertical. In the above description of FIGS 2A to 2d, the reason why the brightness value of each base-point pixel should be lower than those of the referred pixels, such as ref11, ref 12, ...ref 42, is that the penumbra is darker than the background. This condition although can be established on the umbra of an ordinary steel cord, the processing of selecting only pixels having brightness higher than the brightness Bth (S34) has already been carried out, erroneous detection of an umbra can be prevented. Incidentally, a pixel having brightness higher than the brightness Bth although may exist on the penumbra of a normal steel cord, they since do not meet the condition for the line segment filters a1 to a4 that areas on both sides of the pixel of interest should be higher in brightness than the pixel of interest, erroneous detection of the line segment can be prevented. As the result of the above processing, candidates of the penumbra of a wire are aggregated as binary images in the line segment aggregation image 80.

FIGS. 3A to 3C illustrate examples of such a line segment aggregation image. FIG. 3A represents an example of an X-ray image. FIG. 3B is a conceptual rendering thereof and represents an example of appearance of wires 81 to 85. FIG. 3C represents the line segment aggregation image 80 obtained by aggregation by the processing loop of Step S32.

The line segment aggregation image 80 is a binary image. Therefore, regarding a false cord having not enabled to be removed in a previous stage and a wire so minute that it is ignorable, they can be eliminated by removing an isolated point or carrying out labeling during the line segment analysis processing of Step S33, subsequently excluding a line segment having the number of pixels being less than the predetermine number of pixels.

In addition, in the line segment analysis processing of Step S33, when there is a pixel or a label related to the detected line segment obtained as the result of the above processing, it is judged that any wire resulting from "individualized wire" (coming undone-steel cord) has occurred in the relevant image (the relevant frame in X-ray moving images). The line segment detection filters illustrated in FIG. 2 are examples of line segment detection filters and the publicly known edge detection filter described in Non-patent Document 2 can also be used for these line segment detection filters.

Lack of steel cord, contact between steel cords, entangled

steel cords, or "individualized wire" of the steel cord is detected in the relevant frame by the processing described up to this point. Each time frame processing is carried out, the presence or absence of a segment feature, such as lack of steel cord, contact between steel cords, entangled steel cords, or "individualized wire", in the relevant frame is held as a history on a feature-by-feature basis, and the past history is updated. This segment feature history is designated as "frame-by-frame SC segment feature log" and is outputted by the SC trace/segment feature detection part 31. The update history of the coordinates of the SC models described above can also be updated and held in each frame. This update history of the coordinates of the SC models is designated as "SC trace log in frame" and it is also outputted from the SC trace/segment feature detection part 31.

(Frame-By-Frame Quality Judgment Part)

FIG. 26 illustrates an example of a quality judgment condition at the frame-by-frame quality judgment part 32. The frame-by-frame quality judgment part 32 refers to the "frame-by-frame SC segment feature logs", and thereby judges the quality of the steel cord built in a handrail as the object of inspection in each frame. The frame-by-frame quality judgment part 32 updates and holds the frame-by-frame history on which quality judgment was carried out. This frame-by-frame history is designated as "frame-by-frame quality judgment log"

and it is outputted by the frame-by-frame quality judgment part 32.

The quality judgment in each steel cord is carried out by using the following length as measure, namely, how long length
5 a segment feature of "individualized wire" (coming undone-steel cord) lasts in the direction of the length of the steel cord. For example, a predetermine natural number of Sth is set as a threshold value for "individualized wire" in the direction of length. When "individualized wire" lasts for the threshold
10 value or longer, the steel cord is judged as deteriorated (or no good state with serious damage). This result of judgment is recorded in the "frame-by-frame quality judgment log" for each frame. In the case of deteriorated (or no good state with serious damage), the frames containing the segment feature
15 causing "deteriorated (or no good state with serious damage)" are tracked back up to a starting point of the segment feature, so the record in each log from the frame at the starting point of the segment feature up to the frame at the time of judging the segment feature is revised to deteriorated (no good state
20 with serious damage). Thus, the "frame-by-frame quality judgment logs" are updated as mentioned above and held in the memory. In the cases of judging not deteriorated (or good state with normal) (namely "individualized wire" does not last), the judgment of good state with normal is recorded in the
25 "frame-by-frame quality judgment logs" for the frame.

This judgment can be carried out as illustrated in, for example, FIG. 26. A judgment table in FIG. 26, a rank of quality is classified to two levels, "normal" and "deteriorated (or no good state with serious damage)". The right column indicates judgment criteria, and the quality is judged at the frame-by-frame quality judgment part 32. The judgment is outputted as a "frame-by-frame quality judgment logs." In this case, the quality is evaluated in two levels, normal and deteriorated (or no good state with serious damage). Instead, such deterioration can also be evaluated stepwise depending on the number of frame for which the occurrence of "individualized wire" lasts.

Up to this point, description has been given to evaluation by normal and deteriorated (or no good state with serious damage) and stepwise evaluation. When a judgment of deteriorated is made, the necessity for replacement of the handrail may be notified through the display part 34 to prompt maintenance personnel to replace the handrail. In FIG. 26, the predetermined length of Sth is expressed by frames but it can also be expressed by millimeters.

(Final Judgment Part)

Description will be given to the processing by the final judgment part 33. The final judgment part 33 refers to the above-mentioned "frame-by-frame quality judgment logs" and judges the quality of a single handrail as the object of

inspection. For example, when there is no judgment of deteriorated in the "frame-by-frame quality judgment logs" at all, the single handrail can be judged to be a non-defective. When there are the predetermined number or more of judgments of deteriorated in the "frame-by-frame quality judgment logs" that single handrail can be judged to be deteriorated. As a simpler example of the embodiment of the final judgment part 33, the following measure may be taken, namely, the worst quality judgment result recorded in any one of "frame-by-frame quality judgment logs" is taken as the evaluation of the single handrail. Up to this point, description has been given to the processing by the final judgment part 33.

(Flow of Processing by Image processing unit)

FIG. 33 illustrates a flow of the processing by the image processing unit of the inspection apparatus for the handrails of passenger conveyors of the invention.

Description will be given to the flow of the processing by the image processing unit of the inspection apparatus for the handrails of passenger conveyors with reference to FIG. 33. Before an image of the handrail is newly processed, the memory and the parameters used in the processing are initialized (S50). The memory initialization includes, for example, the initiation of the "frame-by-frame SC segment feature logs", "frame-by-frame SC trace logs", and "frame-by-frame quality judgment logs".

In the frame processing loop of Step S51, loop processing is carried out until the processing of moving images required for handrail quality evaluation is completed. When the processing of all the frames to be processed is completed, the
5 flow comes out of this loop and proceeds to the processing of Step S58 (S52). The frame completion determination processing of Step S52 and the frame acquisition processing of Step S53 are carried out at the frame acquisition part 28. Subsequently, the SC detection processing of Step S54 is carried out at the
10 SC detection part 29. Then the SC trace and segment feature detection processing of Step S55 is carried out through the cooperation processing of the SC model holding part 30 and the SC trace/segment feature detection part 31. At the same time, the SC model update processing of Step S56 is carried out
15 regarding the SC model held at the SC model holding part 30. Regarding frames, subsequently, the frame-by-frame quality judgment processing of Step S57 is carried out and each "frame-by-frame quality judgment log" is updated. This processing is carried out at the frame-by-frame quality judgment
20 part 32.

After the above processing is completed for all the required frames, the handrail quality final judgment processing of Step S58 is carried out at the final judgment part 33. At this time, the result of the final judgment may be held in a
25 magnetic medium or may be sent to a quality management server

or the like through a network. The automatic judgment of the handrail quality is implemented by the above processing.

(Example in Which Wire is Detected Only in Place of Occurrence of Lack or the Like)

5 The processing in accordance with the wire detection processing flow (FIG. 1) at the wire detection part 311 can be carried out for all the frames of moving images. Instead, it can also be carried out in conjunction with the presence or absence of a segment feature other than "individualized wire",
10 that is, "contact between steel cords", "lack of steel cord" or "entangled steel cords" detected by the SC trace/segment feature detection part 31. This is because "individualized wire" is prone to occur in frames involving a feature "contact between steel cords", "lack of steel cord", or "entangled steel
15 cords". When frames to be processed in moving images are limited as mentioned above, it is possible to reduce the amount of processing on the entire moving images and contribute to the acceleration of processing.

(Example of Method in Which Brightness Threshold Value Bth is
20 Unfixed)

 Description has been given to how to determine brightness threshold value Bth for identifying whether an image has a penumbra as a condition of a wire or an umbra as a condition of a normal steel cord. The brightness values of the umbra
25 and the penumbra vary depending on the output of an X-ray source,

such as dosage related to current and wavelength related to voltage. They vary also depending on the type of a used scintillator and the gain adjustment of the camera. In the description of the above example, consequently, the brightness
5 threshold value is determined by setting the output of the X-ray source, the type of the scintillator, and the value of camera gain and then plotting such a drawing as illustrated in FIG. 8 to FIG. 13. However, when the thickness of rubber covering steel cords significantly differs from place to place, the fixed
10 brightness threshold value Bth may be insufficient.

So, when Bth is determined by the above plotting, $KthB = Bth/Bbak$, which is a ratio of Bth to the background brightness Bbak, is obtained. KthB is a rational number larger than 0 and smaller than 1. When the positions of independently
15 existing steel cords are determined at the SC trace/segment feature detection part 31, the brightness of the image between the steel cords is measured. This measurement value can be considered as background brightness Bbak. At this time, by obtaining an average value from positions equivalent to
20 backgrounds in several frames, the average value can be taken as the background brightness Bbak. This makes it possible to cancel out an influence of random noise. Thus the deemed background brightness Bbak can be used to automatically adjust the brightness threshold value Bth in accordance with change
25 in circumstances, such as rubber thickness, as represented by

$$B_{th} = K_{th} B \times B_{bak}.$$

When B_{th} is determined by the above plotting, meanwhile, $K_{th} M = B_{min}/B_{th}$, which is a ratio of the umbra brightness B_{min} to B_{th} , can also be determined. $K_{th} M$ is a rational number larger than 0 and smaller than 1. When the positions of independently existing steel cords are determined at the SC trace/segment feature detection part 31, the brightness of an image of each steel cord portion is measured and the measurement value is considered as the umbra brightness B_{min} . As mentioned above, the position of a steel cord detected at the SC detection part 29 is equivalent to a valley portion in a brightness distribution. Therefore, the image brightness in the position of the steel cord can be considered as the umbra brightness B_{min} . At this time, by obtaining an average value from positions equivalent to the steel cord in several frames, the average value can be taken as the umbra brightness B_{min} . This makes it possible to cancel out an influence of random noise. Thus the deemed umbra brightness B_{min} can be used to automatically adjust the brightness threshold value B_{th} in accordance with change in circumstances, such as rubber thickness, as represented by $B_{th} = B_{min}/K_{th} M$.

Here, description will be given to the above measurement of B_{bak} and B_{min} with reference to FIG. 27. FIG. 27 illustrates a brightness measurement method being used when the brightness threshold value B_{th} is unfixed and is a conceptual rendering

of an X-ray image in which there are six normal steel cords. Unlike the other drawings, this drawing illustrates umbras and penumbras so that they are obvious. In the center of each steel cord image, umbras 87 to 92 exist and penumbras 93 to 98 indicated
 5 by hatching exist in the periphery of the umbras. A dot-shaded area 86 occupying substantially the upper half of the drawing is an area where the rubber covering steel cords is thick and the area is darkly shot as a whole. When the area 86 and the other areas are largely different in brightness, a uniformly
 10 fixed brightness threshold value B_{th} may be inappropriate in some cases.

So, it is necessary to take the following measure: that is, in steel cords and their vicinities, a brightness value of each umbra 87 to 92 is measured and taken as B_{min} , and brightness
 15 of areas not being an umbra or a penumbra is selected and taken as the background brightness B_{bak} . As mentioned above, the position of each steel cord detected by the SC detection part 29 is equivalent to a valley portion in a brightness distribution and thus the position of each steel cord is within the range
 20 of each umbra 87 to 92. Therefore, the umbra brightness can be obtained by measuring the brightness in the position of each steel cord. Meanwhile, the brightness of the middle point position between detected steel cords is applied to the background brightness. When steel cords are close to each other,
 25 the penumbras of the adjoining steel cords may overlap with

each other and background brightness cannot be obtained sometimes. Therefore, when adjoining steel cords are so close to each other that their penumbras overlap with each other, it is necessary to stop the measurement of background brightness and apply a previously obtained background brightness value. The above-mentioned method makes it possible to obtain appropriate threshold brightness B_{th} and background brightness B_{bak} even when the brightness fluctuates due to rubber thickness. Proposed is a preferable example of, in an entire image, positioning each detected steel cord as a center position, providing an area used for B_{th} and B_{bak} on the periphery of the detected steel cord, and applying B_{th} and B_{bak} obtained relative to the position of the steel cord into the area.

That is, a brightness range for a criterion of the penumbra caused from "individualized wire" can be variably set by using brightness of the background in the projected image or brightness of the umbra therein as a parameter, with consideration of change in the brightness of the background or change in the brightness of the umbra.

Incidentally, the area 86 is located between the penumbra 95 and the penumbra 96. Regarding background brightness between the steel cords related to the umbra 89 and the umbra 90, the background brightness of the area 86 and that of other areas may be averaged in some cases. It since is a very narrow area for the entire steel cord, however, no problem arises.

(Working Example in Which Trace of Steel Cord is Omitted)

The description of the above working example (Working Example 1) is done of qualities of judgment for the detected objects based on the assumption that "contact between steel
5 cords", "lack of steel cord", "entangled steel cords", and "individualized wire" may occur in steel cords built in a handrail. However, it is acceptable to judge a steel cord (passenger conveyor) about only "individualized wire", when judging only "individualized wire", the judgment is more easily
10 carried out by adopting the image processing in Working Example 2 illustrated in FIG. 28. FIG. 28 illustrates the image processing unit of an inspection apparatus for the handrails of passenger conveyors in Working Example 2. The image processing unit 2 in this working example is comprised of a
15 frame acquisition part 28, a wire detection part 311, a frame-by-frame quality judgment part 32, a final judgment part 33, a display part 34, a command input part 35, and a control part 36.

In this working example, all the frames of moving images
20 related to X-ray photography are acquired at the frame acquisition part 28. The wire detection flow described with reference to FIG. 1 is carried out on them at the wire detection part 311. So, the presence or absence of "individualized wire" is judged on a frame-by-frame basis and a "frame-by-frame SC
25 segment feature log" is outputted. In this log, recorded is

the presence or absence of "individualized wire" in frame-by-frame. The frame-by-frame quality judgment part 32, final judgment part 33, display part 34, command input part 35, and control part 36 are the same as those in Working Example 1 described with reference to FIG. 14.

(Bidirectional Trace Method)

The SC detection part 29 in FIG. 14 is capable of holding an SC detection log table on a frame-by-frame basis and the SC model holding part 30 can be so configured as to hold an SC model log table on a frame-by-frame basis.

The SC model group is used to collate detected each steel cord (SC) with it, as described above, for steel cord trace. The SC model group is updated with a group of pieces of SC data (SC model log table) detected in the immediately previous frame. This is intended to use the immediately previous data on steel cord trace to enhance accuracy. FIGS. 29A to 29C illustrate examples of any SC detection log table and any SC model log table. It will be assumed that the designed number of the steel cords is nine for the prevention of complications of explanation.

For example, FIG. 29A illustrates a SC model log table for the 120th frame. Frame number 120 indicates that the log corresponds to the 120th frame and the numbers 01 to 09 in a column of model cord indicate the numbers (names) assigned to model cords as SC models. FIG. 29B illustrates a SC detection log table for the 121st frame. Frame number 121 indicates that

the log corresponds to the 121th frame and the detected cords as detected steel cords are arranged in the ascending order of magnitude of detected coordinate. "D" in the column of detected cord indicates that a steel cord has been detected and the numbers 1 to 9 are orders arranged based on coordinate but they are not numbers assigned to names of detected cords. In this example, detected are all the steel cords in design. As illustrated with reference to FIG. 20A, the model cords (SC models) of numbers 01 to 09 are updated on coordinates of relevant detected steel cords in the ascending order of coordinates of detected steel cords. For example, in the 121th-frame, when nine steel cords are detected and their coordinates are recorded into the detection log table for the 121st frame as illustrated by FIG. 29B, subsequently, those coordinates of the detected steel cord are used for updating the SC model log table for the 121st frame of FIG. 29C.

FIGS. 30A to 30C illustrate another example of an SC detection log table and an SC model log table. It will be assumed that the design number of the steel cords is nine for the prevention of complications of explanation. For example, FIG. 30A illustrates the SC model log table for the 120th frame. Frame number 120 indicates that the log corresponds to the 120th frame and the numbers 01 to 09 in a column of model cord indicate the numbers (names) assigned to model cords as SC models. FIG. 30B illustrates a SC detection log table for the 121th frame.

Frame number 121 indicates that the log corresponds to the 121th frame and the detected cords as detected steel cords are arranged in the ascending order of the magnitude of detected coordinate. "D" in the column of detected cord indicates that a steel cord has been detected. In this case, only seven steel cords are detected. For example, when it is determined that cord 06 and cord 07 are undetected by the processing described with reference to FIG. 20B, the 01-cord to 05-cord, the 08-cord, and the 09-cord are updated with the detected coordinates of the steel cords in the frame 121. Regarding the undetected 06-cord and 07-cord, their assumed coordinates are obtained by linearly interpolating the coordinate detected 05-cord and the coordinate of the 08-cord, and coordinates of the 06-cord and the 07-cord are updated with the above assumed coordinates. As the result of the above operation, the SC models are also updated even when there is an undetected steel cord.

In this case, if there are too many undetected steel cords or any frame with an undetected steel cord last long, the SC model may be inaccurately updated. To be more specific, when a steel cord undetectable area occurs by cause of entangled steel cords or the like and the undetectable area lasts in the trace process of a forward direction, the length within a certain range (predetermined number of frames) from the undetectable area may be determined as an undetected area. However, in actuality, the trace of a backward direction may reveal that

a steel cord detectable area is longer than the deemed undetected area. To eliminate this problem that a deemed undetected area is excessively set, it is proposed to configure this working example such that bidirectional trace is carried out, that is, steel cords are traced in the order (in the forward direction) of frames and in the opposite order (in the backward direction) to the order of frames. Whether to adopt bidirectional trace is arbitrary.

FIG. 31 illustrates how bidirectional trace is implemented and illustrates a trace method and a trace apparatus comprised of an SC detection part 29, an SC model holding part 30, and an SC trace/segment feature detection part 32.

The SC detection part 29 includes an SC detection log table 99 described with reference to FIG. 29 and FIG. 30 and holds the coordinate of each steel cord detected on a frame-by-frame basis.

The SC model holding part 30 includes an SC model log table forward direction 100 and an SC model log table backward direction 101 described with reference to FIG. 29 and FIG. 30. The SC model is sequentially updated as described with reference to FIGS. 20A to 20C and the log of position coordinate is held together with the cords given names in the SC model log table forward direction 100.

The SC trace/segment feature detection part 32 includes an imperfect counter 102 and an imperfect counter log table

103. When the coordinates of detected steel cords are received from the SC detection part 29 and the number of the detected steel cord is less than the number in design, the imperfect counter 102 is incremented. When the number of detected steel
5 cords agrees with the number in design, the counter is reset.

As the result of this operation, it is possible to learn how many frames involving an undetected steel cord last from the imperfect counter 102. The imperfect counter log table 103 records and holds values indicated by the imperfect counter
10 102 on a frame-by-frame basis. With this configuration, by referring to the imperfect counter log table 103 after the processing of all the frames is completed, it is possible to know that any SC models has been updated with any undetected steel cords in the trace of the forward direction.

15 FIG. 32 illustrates a flow of processing by the image processing unit of the inspection apparatus for the handrails of passenger conveyors in this working example when bidirectional trace is carried out.

Next, description will be given to the flow of the
20 processing by the image processing unit of the inspection apparatus for the handrails of passenger conveyors with reference to FIG. 32. Before images of the handrail are newly processed, the memory and the parameters used in the processing are initialized (S50). The memory initialization includes,
25 for example, the "frame-by-frame SC segment feature log",

"frame-by-frame SC trace log", "frame-by-frame quality judgment log", the SC detection log table 99, SC model log table forward direction 100, SC model log table backward direction 101, imperfect counter 102, and imperfect counter log table 103.

In the frame processing loop of Step S51, loop processing is carried out until the processing of moving images required for handrail quality evaluation is completed. When the processing of all the frames to be processed is completed, the flow comes out of this loop and proceeds to the backward loop processing of Step S60 (S52). The frame completion determination processing of Step S52 and the frame acquisition processing of Step S53 are carried out at the frame acquisition part 28. Subsequently, the SC detection processing of Step S54 is carried out at the SC detection part 29. Then the SC trace processing of Step S59 is carried out through the cooperation processing of the SC model holding part 30 and the SC trace/segment feature detection part 31. At the same time, the SC model update processing of Step S56 is carried out for the SC model held at the SC model holding part 30. During the processing of Steps S54, S59, and S56, the SC detection log table 99, SC model log table forward direction 100, imperfect counter 102, and imperfect counter log table 103 are updated as mentioned above. The frame-by-frame segment feature extraction or quality judgment is not carried out here because

they are carried out in the backward trace.

After the SC trace in the forward direction is completed, the SC trace/segment feature detection part 32 resets the imperfect counter (S70) and then starts SC trace in the backward order of frames (S60). At this time, obtained from the SC detection part 29 are the number and coordinates of the steel cords obtained by referring to the SC detection log table 99 in the backward order of frames, but not steel cords newly detected by the processing described with reference to FIG. 15 to FIG. 19 (S62).

When the number of the steel cords is less than the number in design, the imperfect counter 102 is incremented. Contrarily, when the number of the steel cords agrees with the number in design, the imperfect counter is reset (S62).

The SC model is updated by the operation described with reference to FIGS. 20A to 20C and the SC model log table backward direction 101 is updated (S63). At this time, referred are the imperfect counter 102 in the current frame and a record of the relevant frame in the imperfect counter log table 103. Then the value on the imperfect counter 102 and the value recorded in the imperfect counter log table 103 are compared with each other. When the value recorded in the imperfect counter log table 103 is smaller than the value on the imperfect counter 102, it can be determined that the result of the trace in the forward direction carried out first is higher in reliability

than that of the backward direction. In this case, consequently, the values in the SC model holding part 30 are replaced with each steel cord coordinate recorded in the SC model log table forward direction 100 (S63).

5 As the result of this processing, the SC model can be updated with the more reliable value between values from the bidirectional trace. Using the result of the SC trace, a feature of "contact between steel cords", "lack of steel cord", "entangled steel cords" or "individualized wire" is detected
10 on a frame-by-frame basis and the "frame-by-frame SC segment feature log" and the "frame-by-frame SC trace log" are updated (S64). Subsequently, the frame-by-frame quality judgment processing of Step S65 is carried out on the frame, and the "frame-by-frame quality judgment log" is updated. This
15 processing is carried out at the frame-by-frame quality judgment part 32.

After the above processing is completed for all the required frames, the handrail quality final judgment processing of Step S58 is carried out at the final judgment part 33. At this time,
20 the result of the final judgment may be held in a magnetic medium or may be sent to a quality management server or the like through a network. The automatic judgment of the handrail quality is implemented by the above-mentioned processing.

(Wire Detection Apparatus Based on Visible Light)

25 Next, description will be given a wire detection apparatus

as another working example of an inspection apparatus for continuous members for transport mechanisms. The wire detection apparatus acquires an image of a wire of a cover-free belt or rope by visible light but not by an X-ray, and detects it.

FIG. 34 illustrates an imaging system for detecting a wire by visible light. The imaging system is comprised of a cover 104 for blocking outside light, a camera 7 with a lens portion being inserted into the cover 104, a light source 107 having a finite size, a screen 106 and an image processing unit 2 not illustrated in FIG. 34.

The screen 106 is relatively thin like Japanese shoji paper, and upon an object being placed in proximity to the broken line 105, a shadow (projected shadow) is formed on the screen so as to be shot with the camera. Before the inspection processing, for an object 109 having a reference outside diameter, tangential lines 110 to the object 109 are drawn from both ends of the light source 107, and a position 105 of the object is adjusted such that the tangential lines intersect with each other at one point on the screen 106. With this configuration, for an object 108 having an outside diameter larger than the reference outside diameter 109, an appearance on the screen 106 is an umbra formed by completely blocking the light source 107. Contrarily, for an object, such as a wire individualized from a rope or a belt, having an outside diameter smaller than

the reference outside diameter 109, an appearance is a penumbra formed by blocking a part of the light source 107. The wire can be detected by receiving its image with the image processing unit 2 through the camera 7 and by carrying out the wire detection processing described with reference to FIG. 1.

Up to this point, description has been given to working examples of the configuration of image processing apparatuses of the invention.

According to the working examples, the quality of a handrail can be judged as no good state with serious damage when the occurrence of "individualized wire" of a steel cord lasts for a predetermined length or longer in the direction of the length of the handrail. Therefore, it can be determined of the replacement of the handrail as required and prevent erroneous judgment and unnecessary handrail replacement.

When the "individualized wire" of a steel cord is at such a level that it is not determined as seriously damaged, the quality of the handrail is judged as a caution state with light damage with the "individualized wire" of the steel cord to be taken into account. In the other cases, the handrail is judged as a good state with normal. Therefore, when the quality of a handrail is judged as deteriorated, it can be known that the time to replace the handrail is approaching. The quality of each handrail can be evaluated in three or more levels (for example, the levels of no good state with serious damage, a

caution state with light damage, and a good state with normal, and the like).

Up to this point, the invention has been described based on working examples. However, the above configuration
5 described in relation to each working example is just an example and the invention can be appropriately modified without departing from the technical idea thereof.

The configurations described in relation to each working example may be combined unless there is a contradiction
10 therebetween. The "inspection" cited in this specification may also be designated as "checkup" and the "inspection" cited in this specification and appended claims includes "checkup." Similarly, the "maintenance" cited in this specification may also be designated as "servicing" and the "maintenance" cited
15 in this specification and appended claims includes "servicing." Maintenance (servicing) refers to that any one of inspection (checkup), repair, and replacement is carried out and it includes cases where two or more of them are combined and carried out.

WHAT IS CLAIMED IS:

1. An inspection apparatus for continuous member including a steel cord, which is used in a transport mechanism, configured by helically laying up plural individualized wires, comprising:

5 an imaging unit that applies X-rays or visible light to form a projected image of the steel cord as an object of inspection; and
an image processing unit that receives the projected image from the imaging unit, carries out image processing upon the projected image and detects the individualized wire protruding from the steel
10 cord coming undone with extracting a line segment thinner than a normal steel cord and higher in brightness than the normal steel cord from the projected image.

2. The inspection apparatus according to Claim 1,

15 wherein the imaging unit is configured to form an umbra for a steel cord having a normal outside diameter and form a penumbra thinner than the umbra of the normal steel cord for the individualized wire, and

wherein the image processing unit is configured to set a range
20 of brightness used as a criterion for the penumbra arising from the individualized wire and to extract a line segment equivalent to the individualized wire based on the criterion.

3. The inspection apparatus according to Claim 1,

25 wherein, upon the length of an extracted line segment

being larger than the criterion value, the image processing unit is configured to determine "individualized wire" of the steel cord.

5 4. The inspection apparatus according to Claim 1,
 wherein the continuous member is a steel wire-built in
handrail for passenger conveyor, and the image processing unit
is an X-ray imaging device.

10 5. The inspection apparatus according to Claim 1,
 wherein the continuous member is a bare steel cord becoming
a wire rope for elevators and the imaging unit is a visible
light imaging device.

15 6. The inspection apparatus according to Claim 1,
 wherein the image processing unit is configured to use
a steel cord model for tracing the steel cord in each of frames
of the projected images and thereby to detect at least one of
lack of steel cord, contact between steel cords, entangled steel
20 cords.

 7. The inspection apparatus according to Claim 6,
 wherein the steel cord model is set such that the steel
cord model is updated with a detected steel cord shot in an
25 image frame immediately before.

8. The inspection apparatus according to Claim 6,

wherein the image processing unit is configured to set such that the steel cord is traced bidirectionally in a forward direction and in a backward direction, and the trace in the backward direction is carried out using steel cord data stocked as a result of the trace in the forward direction.

9. The inspection apparatus according to Claim 2,

wherein the range of brightness used as the criterion for the penumbra arising from the individualized wire is set to be variable with brightness of a background in the projected image or brightness of the umbra taken as a parameter.

10. The inspection apparatus according to Claim 1,

wherein the imaging unit includes an X-ray tube having an X-ray exit larger in horizontal and vertical sizes than an outside diameter of a steel cord becoming individualized wire to be detected, or a visible light source having a visible light ray exit larger in horizontal and vertical sizes than the outside diameter of the steel cord becoming the individualized wire to be detected,

wherein the X-ray tube or the visible light source, the continuous member including the steel cord to be subjected to inspection, and a conversion plate that reflects a projected

image, are arranged in a geometrical relation in which the following intermediate outside diameter-steel cord is not reflected as a projected image of an umbra onto the conversion plate, and

5 wherein the intermediate outside diameter-steel cord is a steel cord having an intermediate outside diameter between the outside diameter of the individualized wire and the outside diameter of the normal steel cord.

10 11. The inspection apparatus according to any one of Claims 1 to 10,

 wherein the image processing unit has a steel cord model in which the number of steel cords in design and a barycenter coordinate of each steel cord can be updated and held, and

15 the image processing unit is configured to update each barycenter coordinate in the steel cord model such that the total sum of differences between barycenter coordinates of the respective detected steel cord and barycenter coordinates of the respective steel cord models is minimized.

20 12. The inspection apparatus according to Claim 11,
 wherein a frame counter that counts the number of lasting frames in which the number of detected steel cords is less than the number of steel cords in design, and

25 wherein the image processing unit includes a memory that

memorizes to hold the followings as log data in each frame:
namely, barycenter coordinates of frame-by-frame detected
steel cords, frame-by-frame updated barycenter coordinates in
the steel cord model, the number of the detected steel cords,
5 the value on the frame counter.

13. The inspection apparatus according to Claim 12,
wherein the image processing unit is provided with a second
steel cord model in addition to the previous steel cord model,
10 and,

the image processing unit is configured to, after tracing
is a forward direction while updating the previous steel cord
model upon the entire shot moving images, sequentially trace
in a backward direction while updating the barycenter
15 coordinates in the second steel cord models in the descending
order of frame number on a frame-by-frame basis such that the
total sum of differences between barycenter coordinates of the
respective detected steel cord held in log data and barycenter
coordinates of the respective second steel cord models is
20 minimized, and

wherein the image processing unit is further configured
to, on condition that the value in log data of the frame counter
obtained upon trace being carried out in the forward direction
is smaller than the value of the frame counter obtained upon
25 trace being carried out in the backward direction, barycenter

coordinates in the respective second steel cord models are replaced with barycenter coordinates in the respective previous steel cord models.

5 14. An inspection method for continuous member including a steel cord, which is used in a transport mechanism, configured by helically laying up plural individual wires, comprising the following steps of:

 applying X-rays or visible light to form a projected image
10 of the steel cord as an object of inspection;

 carrying out image processing upon the projected image; and

 detecting the individualized wire protruding from the steel cord coming undone with extracting a line segment thinner than a normal steel cord and higher in brightness than the normal
15 steel cord from the projected image.

 15. The inspection method for continuous members for transport mechanisms according to Claim 14,

 wherein, at the step of forming the projected image, forming
20 an umbra for a steel cord having a normal outside diameter and forming a penumbra thinner than the umbra of the normal steel cord for the individualized wire, and

 wherein, at the image processing step, set a range of brightness used as a criterion for the penumbra arising from
25 the individualized wire and to extract a line segment equivalent

to the individualized wire based on the criterion.