

INSPECTION APPARATUS FOR HANDRAIL OF PASSENGER CONVEYER AND MAINTENANCE METHOD OF PASSENGER CONVEYER

BACKGROUND OF THE INVENTION

Field of the Invention

The invention relates to an inspection apparatus for a handrail of a passenger conveyer and a maintenance method of the passenger conveyer.

5 Description of the Related Arts

Handrails serving as guardrails which move synchronously with steps adapted to put a passenger thereon are provided for a passenger conveyer such as escalator, moving footpath, or the like. The user grasps the handrail and keeps stability. The handrail has such a structure that wires made of steel (or belts made of steel) called a plurality of steel cords
10 (hereinbelow, there is also a case where they are abbreviated to SC) are fixed by rubber for holding and an outside of each SC is covered with a sheath made of makeup rubber. If the holding rubber is lightly damaged by an aging change and loses a function for fixing the steel cords, unfixed steel cords start to occur in the handrail due to a driving apparatus for moving the handrail. Soon, those steel cords rub mutually and are fragmented.

15 To judge the light damage of the steel cords, JP-A-10-10060 discloses such a technique that a handrail having steel cords therein is sandwiched and is X-ray transmission photographed, the handrail is moved in accordance with necessity and is also photographed, and a state of the steel cords is observed by a visual inspection.

JP-A-2005-126175 discloses such a technique that a two-dimensional power
20 spectrum is calculated from X-ray images photographed by a construction similar to that disclosed in JP-A-10-10060, and a uniformity of intervals between the steel cords or the presence or absence of a skew or intersection of the steel cords is automatically judged from a pattern of the power spectrum.

Although the light damage of the steel cords of the passenger conveyer is not
25 judged, JP-A-2008-309649 discloses such a technique that a steel belt in a rubber tire is X-ray photographed, images which were continuously photographed in the circumferential direction of the tire are adhered so as to form a panorama image, after that, it is processed, an outline of the steel belt is extracted, thereafter, a width in the direction at a right angle to a circumference is measured at regular intervals in the circumferential direction, and if the widths are discontinuous,
30 it is judged that the steel cord has seriously been damaged.

Although the light damage of steel cords of the passenger conveyer is not judged,

JP-A-2010-54289 discloses a method of detecting a break of a linear pattern. According to such a method, two virtual lines are provided on the linear pattern, in the case of tracing an outline of the linear pattern from one virtual line and returning to the same virtual line, it is judged that the break exists on the linear pattern. On the other hand, in the case of tracing the
5 outline of the linear pattern from one virtual line and reaching the other virtual line, it is judged that in a region sandwiched between the two virtual lines, it is determined that no breaks exist on the linear pattern in a region sandwiched between the two virtual line.

SUMMARY OF THE INVENTION

The handrail of the passenger conveyer is gradually lightly damaged due to the
10 elapse of time. Particularly, after the holding function of the holding rubber was lost, the steel cords are also gradually lightly damaged due to the contact or entanglement. In order to accurately grasp exchange timing of the handrail, it is necessary to correctly judge a grade of the light damage. First, the light damage of the steel cords starts from such a phenomenon that an unfixed steel cord, that is, a displacement occurs in the direction at a right angle to the moving
15 direction (longer direction). Subsequently, the adjacent steel cords are come into contact with each other. Further, the steel cords which are not inherently neighboring are entangled with each other. After that, the entangled steel cords rub with each other and are fragmented and a lack of the steel cord occurs. When such a state occurs, an X-ray image in which the steel cord lacks from a position where it should inherently exist is obtained. It is judged that it is
20 necessary to exchange the handrail in which the entanglement or lack has occurred. In order to properly maintain the apparatus, it is necessary to judge such a graded light damage state, that is, a start grade of the unfixed steel cord, a contact grade of the adjacent steel cords, an entanglement occurrence grade, and a lack state (lack) of the steel cord due to the fragmentation.

When the X-ray photographed image is processed and the unfixed steel cord or
25 the contact, lack, or entanglement of the steel cords is detected, if a judgement reference is severely set, there is a possibility of misjudgement. In the case of the slight unfixed steel cord, contact, lack, or entanglement, since it is not always necessary that the handrail has to be exchanged, there is also a case where there are no problems on quality of the handrail.

According to the technique disclosed in JP-A-10-10060, since the light damage of
30 the steel cord is judged by the visual inspection, there is such a problem that a variation in judgment and an overlooking by maintenance persons are liable to occur.

According to the technique disclosed in JP-A-2005-126175, the uniformity of the steel cords or the presence or absence of the skew or intersection of the steel cords is

quantitatively judged based on the power spectrum. The intersection can be applied to detection of the entangled steel cords. It is considered that the lack of the steel cord can be also detected from the presence or absence of the power spectrum. However, the uniformity or skew is not a feature which is directly concerned with the light damage grade of the steel cord. Therefore, according to the above technique, it is difficult to precisely detect the unfixed steel cord or the presence or absence of the contact and there is such a problem that it is difficult to make the graded judgement about the light damage. There is also such a problem that a length of lack, entanglement, or the like cannot be detected.

According to the technique disclosed in JP-A-2008-309649, the uniformity of the widths in the circumferential direction is measured from the outline of the steel belt. However, according to such a technique, since three or more steel cords cannot be traced, there is such a problem that it is difficult to detect the presence or absence of a feature such as contact, entanglement, lack, or the like.

According to the technique disclosed in JP-A-2010-54289, in order to trace the outline of the linear pattern, such a necessity that each segment of the image is accessed at random in accordance with the linear pattern is caused. Thus, since an amount of arithmetic operation processings is increased, there is such a problem that it is difficult to execute a high speed processing or, in the case of a handy type PC of a low price, the processing cannot be completed within a permissible time.

The invention is made in consideration of the foregoing problems and it is a first object of the invention to judge a damage of quality of the handrail by detecting entanglement or lack of the steel cords by processing images obtained by photographing the handrail of the passenger conveyer by the X-ray. Further, it is a second object of the invention to provide an inspection apparatus for a handrail of a passenger conveyer in which an unfixed steel cord or a contact, entanglement, or lack of the steel cords is detected, and quality of the handrail can be automatically evaluated at three or more grades from one or a combination of them, and to provide a maintenance method of the passenger conveyer using such an inspection apparatus.

The above and other objects of the present invention will become apparent from the following whole description and the drawings of the invention.

According to the invention, images obtained by photographing a handrail of a passenger conveyer by an X-ray are processed, entanglement or lack of the steel cords is detected, and a damage of quality of the handrail is judged. Alternatively, an unfixed steel cord or a contact, entanglement, or lack of the steel cords is detected and quality of the handrail is automatically evaluated at three or more grades from one or a combination of them. In this

instance, with respect to the contact, entanglement, or lack of the steel cords, a judgement result about whether or not each of those features continues in the longer direction of the handrail by a predetermined length or more is used as one of judgment references. A damage of quality of the handrail is judged, or quality of the handrail is evaluated at three or more grades such as "serious damage", "light damage", and "good quality" by using the detected features.

As a construction of an inspection apparatus for a handrail of a passenger conveyer of the invention, for example, the following construction can be used.

- (1) The apparatus has: an X-ray photographing unit for photographing the handrail of the passenger conveyer by an X-ray; and an image processing unit for processing images photographed by the X-ray photographing unit, detecting a lack or entanglement of steel cords built in the handrail, and judging that quality of the handrail is "serious damage" in the case where a length of lack or entanglement of the steel cords in the longer direction of the handrail continues by a predetermined length or more.
- (2) In (1), the image processing unit detects a contact between the steel cords and judges that the quality of the handrail is "light damage" in the case where both of the lengths of the lack and entanglement of the steel cords in the longer direction of the handrail are shorter than the predetermined length and a length of the contact between the steel cords in the longer direction of the handrail continues by the predetermined length or more.
- (3) In (2), the image processing unit judges that the quality of the handrail is "good quality" in the case where all of the lengths of the lack, entanglement, and contact of the steel cords in the longer direction of the handrail are shorter than the predetermined length.
- (4) In (2), the image processing unit detects the unfixed steel cord in which a position of the steel cord is deviated from an inherent position of the steel cord by a predetermined distance or more in the direction at a right angle to the longer direction of the handrail, and judges that the quality of the handrail is "light damage" in the case where the length of the lack or entanglement of the steel cords in the longer direction of the handrail is shorter than the predetermined length and the unfixed steel cord has occurred.
- (5) In (4), the image processing unit judges that the quality of the handrail is "good quality" in the case where all of the lengths of the lack, entanglement, and contact of the steel cords in the longer direction of the handrail are shorter than the predetermined length and the unfixed steel cord does not occur.

According to a maintenance method of the passenger conveyer of the invention, for example, the quality of the handrail is judged by a method similar to the judging method which is executed in the image processing unit in (1) to (5). If it is judged that the quality of

the handrail is "serious damage", the handrail is repaired, exchanged, or exchanged after the repair. If it is judged that the quality of the handrail is "light damage", the handrail which was judged to be the quality of "light damage" is inspected again at a period shorter than a normal inspection period.

The foregoing construction is merely an example and many modifications of the invention are possible within a scope without departing from the technical idea of the present invention. Examples of constructions of the invention other than the foregoing construction will become apparent from the following whole description and the drawings of the invention.

According to the (1) of the invention, in the case where the length of lack or entanglement of the steel cords in the longer direction of the handrail continues by the predetermined length or more, it is judged that the quality of the handrail is "serious damage". Therefore, it will be understood that it is necessary to exchange the handrail, and the misjudgement and the unnecessary exchange of the handrail can be suppressed.

According to the (2) to (5) of the invention, in the case where the lack or entanglement of the steel cords is in such a state that the quality of the handrail is not judged to be "serious damage", it is judged that the quality of the handrail is "light damage" in consideration of the contact between the steel cords or the unfixed steel cord. In the other cases, it is judged that the quality of the handrail is "good quality". Therefore, if it is judged that the quality of the handrail is "light damage", it will be understood that the exchange timing of the handrail is approaching. The quality of the handrail can be evaluated at multigrades such as three or more grades (for example, grades such as "serious damage", "light damage", "good quality", and the like).

Other advantages of the invention will become apparent from the following whole description.

BRIEF DESCRIPTION OF THE DRAWINGS

Figs. 1A and 1B are diagrams showing an apparatus construction of an inspection apparatus (X-ray inspection apparatus) for a handrail of a passenger conveyer of the invention and an example of attachment of the apparatus to the handrail;

Fig. 2 is a diagram showing an example of a handrail X-ray image;

Fig. 3 is a diagram showing an embodiment of an image processing part of the X-ray inspection apparatus of the invention;

Fig. 4 is a diagram showing a first example of processings of an SC detection part;

Fig. 5 is a diagram showing an example of a contrast compensation of the SC detection part;

Fig. 6 is a diagram showing an example of a detection of a temporary segment of

a steel cord of the SC detection part;

Fig. 7 is a diagram showing a coupling processing of the temporary segments of the steel cord of the SC detection part;

Fig. 8 is a diagram showing a second example of the processings of the SC
5 detection part;

Fig. 9 is a diagram showing a collation method of an SC model and a detected steel cord;

Fig. 10 is a diagram showing a flow for processings of an SC model holding part and an SC trace/segment feature detection part;

Fig. 11 is a diagram showing a detection method of a segment feature "lack" in
10 the SC trace/segment feature detection part;

Fig. 12 is a diagram showing a detection method of a segment feature "contact" in the SC trace/segment feature detection part;

Fig. 13 is a diagram showing a detection method of a segment feature
15 "entanglement" in the SC trace/segment feature detection part;

Fig. 14 is a diagram showing a quality judgement or graded quality evaluation condition in a quality judgement part in every frame;

Fig. 15 is a diagram showing a flow for processings of an image processing part of the X-ray inspection apparatus of the invention;

Fig. 16 is a diagram showing a second embodiment of the image processing part
20 of the X-ray inspection apparatus of the invention;

Fig. 17 is a diagram showing a panorama forming processing of the image processing part of the X-ray inspection apparatus of the invention; and

Fig. 18 is a diagram showing an example of a panorama display of the image
25 processing part of the X-ray inspection apparatus of the invention.

DESCRIPTION OF THE EMBODIMENTS

Embodiments of the invention will be described with reference to the drawings. In each of the drawings and embodiments, the same or similar component elements are designated by the same reference numerals and their description is omitted.

30 [Photographing construction and example of attachment]

Figs. 1A and 1B are diagrams showing an apparatus construction of an inspection apparatus (X-ray inspection apparatus) for a handrail of a passenger conveyer of the invention and an example of attachment of the apparatus to the handrail. Fig. 1A is a diagram showing

the example of the apparatus construction and the apparatus is constructed by an X-ray photographing unit 1 and an image processing part (image processing unit) 2. The image processing part 2 is constructed by, for example, a PC or the like. An encoder 3 is added in accordance with necessity.

5 The X-ray photographing unit 1 is constructed by an X-ray tube 5, a scintillator 6, and a camera 7. The X-ray photographing unit 1 has such a structure that a part of a handrail 4 can be built therein and is constructed in such a manner that the handrail 4 is located between the X-ray tube 5 and the scintillator 6. An X-ray is emitted from the X-ray tube 5 so as to have an extent, is transmitted through the handrail 4, and irradiates the scintillator 6. The scintillator 6
10 is a fluorescent plate which performs a fluorescence when the X-ray is irradiated thereto. The scintillator 6 performs a fluorescence at a luminance according to an irradiation amount of the X-ray. The handrail 4 includes steel cords made of steel therein and a thickness of rubber differs depending on its location. Therefore, an image serving as a shadow picture according to an X-ray transmittance is generated in the scintillator 6. The image generated in the scintillator 6 is
15 fetched to the camera 7. In order to shut off light in the outside of the apparatus, the X-ray photographing unit 1 can efficiently fetch only the image generated by light emission of the scintillator 6. The camera 7 is connected to the image processing part 2 and the image is fetched as electronic data to the image processing part 2.

Fig. 1B is an example in which the X-ray photographing unit 1 is attached to the
20 handrail. The X-ray photographing unit 1 is attached so that a part of the handrail 4 is built therein. As a passenger conveyer, in an escalator which is disposed between an upper floor and a lower floor and has steps 8 adapted to put a passenger thereon, an example in which the X-ray photographing unit is attached to the handrail 4 in a slope portion is illustrated. However, the attaching position is not limited to such a location. Upon X-ray photographing, the X-ray
25 photographing unit 1 and the handrail 4 are relatively moved. That is, the X-ray photographing unit 1 is fixed and the handrail 4 is moved, or the X-ray photographing unit 1 is moved in a state where the handrail 4 is at rest. Thus, a desired position of the handrail 4 can be photographed. In the case where images are continuously photographed as moving images and are stored as movies (moving image file) into a storing unit such as a magnetic medium or the like of the
30 image processing part 2, for example, an MPEG format or an AVI format can be used.

Fig. 2 is an example of the handrail X-ray image photographed by the X-ray inspection apparatus of the invention. A lateral direction of the drawing is the longer direction of the handrail 4. The handrail is photographed in a relatively short field of view of about 5 to 20 mm in the longer direction. Each steel cord is reflected as a black line segment (dark

portion) because its X-ray transmittance is low. A portion (background) between the steel cords is brightly reflected (bright portion) because it is made of only rubber and its X-ray transmittance is relatively high. In this example, each peripheral portion (an upper edge and a lower edge of the drawing) of the handrail 4 is darkly reflected because it is made of thick rubber and its X-ray transmittance is low. In this instance, 18 steel cords are reflected and, for convenience of explanation, it is assumed that they are called "01 cord", "02 cord", ..., and "18 cord" in order from the upper portion to the lower portion of the drawing. Luminance distribution on the left side of the drawing shows distribution of luminance on a line segment in the direction (vertical direction of the drawing; called a "transverse direction" or a direction at a right angle to the longer direction of the handrails) which transverses the handrail by an arrow 9. The steel cord is a valley portion of the luminance distribution. In the peripheral portion made of thick rubber, its luminance is small and its contrast is also lower than that of a center portion.

If the handrail 4 is photographed while moving the X-ray photographing unit 1 or the handrail 4 at a predetermined speed, although a field of view as one image is equal to about 5 to 20 mm, the whole handrail of tens of meters can be photographed as a moving image.

Although it is desirable that the X-ray photographing unit 1 or the handrail 4 which is being photographed is moved at the predetermined speed, even if it is moved at a non-stationary speed, the image can be compensated by using the encoder 3. The encoder 3 is fixed to the X-ray photographing unit 1, measures a relative movement amount of the movement relative to the handrail 4, and transmits the movement amount to the image processing part 2. In the image processing part 2, if the image is extracted every movement of a predetermined distance on the basis of distance information of the encoder 3 from the moving image obtained by the X-ray photographing unit 1, the moving image of the handrail 4 which moves virtually at the predetermined speed can be obtained.

[Image processing part of X-ray inspection apparatus]

Fig. 3 shows an embodiment of the image processing part of the invention which can be embodied by, for example, the image processing part 2. The image processing part is constructed by: a frame obtaining part (frame obtaining unit) 12; a steel cord detection part (steel cord detection unit) (hereinbelow, referred to as an SC detection part) 13; a steel cord model holding part (steel cord model holding unit) (hereinbelow, referred to as an SC model holding part) 14; a steel cord trace/segment feature detection part (steel cord trace/segment feature detection unit) (hereinbelow, referred to as an SC trace/segment feature detection part) 15; a quality judgement part in every frame (quality judgement unit in every frame) 16; a final judgement part (final judgement unit) 17; a display part (display unit) 18; a command input part

(command input unit) 19; and a control part (control unit) 20.

The longer direction of the handrails is expressed by "longer direction" and the direction at the right angle to the longer direction is expressed by "right-angled direction" hereinbelow for convenience of explanation.

5 The frame obtaining part 12 extracts one frame from the moving image photographed by the camera 7, extracts a range of a field of view in which the steel cords are included from the frame, and performs a removal of random noises and a contrast compensation to an image luminance.

10 The SC detection part 13 detects a steel cord portion corresponding to the steel cord which exists independently from the luminance distribution of the image and calculates its coordinates. The coordinate in the right-angled direction of its center of gravity, that is, in the upper/lower direction of the drawing in Fig. 2 is represented as a position of the steel cord in the frame.

15 The SC model holding part 14 updates an SC group model constructed by a predetermined number of cords and holds the updated model. As for the SC group model, together with the coordinate in the right-angled direction of each steel cord, information of a luminance of the steel cord region and a luminance of a background region adjacent thereto is updated and held. The steel cords in the SC group model are labeled as "01 cord", "02 cord", ..., "18 cord", and the like in Fig. 2, respectively.

20 The SC trace/segment feature detection part 15 compares the representative coordinate of the steel cord as an output of the SC detection part 13 with the coordinates of the SC group model held in the SC model holding part 14 and performs a correspondence allocation processing so as to minimize a difference among the synthetic coordinates of the predetermined number of cords. By this processing, to which one of the cord numbers, that is, "01 cord", "02 cord", ..., and "18 cord" in Fig. 2 of the steel cords each steel cord detected in the present frame
25 corresponds is determined. On the basis of such a correspondence relation, the presence or absence of the lack, contact, and entanglement in the present frame of each steel cord is detected and stored as "SC segment feature log in each frame" into the memory. The representative coordinate of each steel cord is used for the updated information of the SC group model in the
30 SC model holding part 14. The coordinate of each steel cord of the updated SC group model is stored as "SC trace log in each frame" into the memory.

With reference to the "SC segment feature log in each frame", the quality judgement part 16 in every frame confirms the segment feature occurring in the present frame, that is, the presence or absence of the lack, contact, and entanglement of the steel cord and in

how many frames those features continue. If they continue by a predetermined number of frames or more, "serious damage" is recorded in a quality judgement log in every frame. If they do not continue by the predetermined number of frames or more, "good quality" is recorded. In the case of "serious damage", the present frame is traced back to the frame in which the relevant segment feature occurred and "serious damage" is recorded again in all of the logs between the present frame and such a frame. In this manner, the "quality judgement log in every frame" is updated and stored into the memory. A quality judgement in multigrades can be also stored as a log by using a result of the AND of the presence or absence of a plurality of segment features.

With reference to the whole "quality judgement log in every frame", the final judgement part 17 judges the quality of the whole handrail samples and outputs as a final judgement result.

The command input part 19 is realized by a well-known command input device such as keyboard, mouse, or the like and can control the start and stop of the processing of the image processing part 2 through the control part 20.

As a display part 18, a well-known graphical user interface such as a display of the PC or the like can be used. Together with the image photographed by the camera 7, the quality judgement result output by the final judgement part 17 can be displayed on the display part 18.

In order to urge the maintenance person who uses the X-ray inspection apparatus of the invention to pay attention, it is also possible to construct in such a manner that the processing of the image processing part 2 of the invention can be finished only by inputting the same result as the result which is output from the final judgement part 17 to the command input part 19. The construction of the image processing part has been described above.

[Frame obtaining part]

The frame obtaining part 12 sequentially extracts the frames from the obtained moving image and processes them. This processing may be constructed as an on-line processing, that is, in such a manner that each time the frame is received from the camera 7, it is successively processed. Or, the processing may be constructed as an off-line processing, that is, in such a manner that after the whole measured portion of the handrail 4 was temporarily stored as movies (moving image file) into a magnetic storing device, it is read out and processed. By using the off-line processing, the processing can be executed without applying an excessive load to the image processing part 2.

In the case where the X-ray photographing unit 1 or the handrail 4 is moved at the

non-stationary speed and the on-line processing is executed based on the distance information of the encoder 3, the frame obtaining part 12 obtains and processes the frame in accordance with an output of the encoder 3 each time the handrail 4 is moved by a predetermined distance of, for example, 5 to 20 mm. In the case of the off-line processing, it is possible to construct in such a manner that the frame obtaining part 12 obtains the frame in accordance with the output of the encoder 3 each time the handrail 4 is moved by a predetermined distance of, for example, 5 to 20 mm, constructs sampling movies (sampling moving image file), and temporarily stores them into the magnetic storing device. The movies formed by such a construction are the moving image of the handrail which is moved at the predetermined speed. The frame obtaining part 12 reads the moving image and can obtain and process it one frame by one. In the case of executing the off-line processing, the function for storing the obtained images as movies is not indispensable to the frame obtaining part 12 and the moving image may be independently formed by moving image forming software.

Relations among the moving speed of the handrail 4, a length of the field of view in the handrail longer direction of the handrail X-ray image shown in Fig. 2, and a moving image frame rate of the camera 7 are shown here. When the frame rate of the camera 7 is equal to N frames per second, a time interval between the frames which are output from the camera 7 is equal to $1/N$ second. On the other hand, if the moving speed of the handrail 4 is equal to L millimeters per second, the handrail 4 is moved by L/N millimeters for a time interval during which the camera 7 obtains one frame. Therefore, assuming that a shutter of the camera 7 is open, if the length of the field of view in the longer direction of the handrail 4 is larger than L/N millimeters, the whole image information of the handrail 4 is included in the movies.

For example, if the frame rate of the camera 7 is equal to 30 frames per second and the moving speed of the handrail 4 is equal to 500 millimeters per second, a movement amount for a time interval until one frame is obtained is equal to $500/30 \approx 16.7$ millimeters. Therefore, if the length of the field of view of the handrail X-ray image is equal to 17 millimeters or more, the whole image information of the handrail 4 is included in the movies. If a camera of an interlace type is used as a camera 7, two images whose obtaining time differs by about 16.7 milliseconds are included as an even-number field and an odd-number field in each of 30 frames which are obtained per second. If they are separated and processed as two images, the images are obtained substantially at a frame rate of 60 frames per second. In this case, the movement amount for a time interval until one frame is obtained is equal to $500/60 \approx 8.3333$ millimeters. Therefore, if a length in the longer direction of the handrail of the handrail X-ray image shown in Fig. 2 is equal to 8.4 millimeters or more, the whole image information of the handrail 4 is

included in the movies.

[SC detection part]

Subsequently, the SC detection part 13 will be described. Fig. 4 is a diagram showing a first example of processings of the SC detection part and shows a flow of the processings. The X-ray image by the frame obtaining part 12 is projected in the longer direction of the handrail as shown in, for example, Fig. 2 and projection luminance distribution is formed (S1). By projecting, random noises of the luminance accompanied by the X-ray photographing are set off and a tendency of the luminance according to the location of the handrail can be measured by a difference of the thickness of rubber. A contrast compensation curve is formed (S2) from a projection profile in S1. Subsequently, the HR right-angled direction line is set to a left edge in the longer direction in order to analyze while the luminance distribution in the right-angled direction of the X-ray image is skipped from the left edge to the right edge one line by line or every predetermined lines (S3).

After that, a loop processing is executed in the longer direction of the handrail (shown by HR in Fig. 4) (S4) and an analysis in the range of field of view of the X-ray image by the frame obtaining part 12 is performed. That is, in the set line, the luminance distribution obtained by performing the smoothing and contrast compensation to the obtained luminance distribution is formed (S5) and a temporary segment of the steel cord is detected (S6). The temporary segment of the steel cord is a pixel having a possibility that it is a portion of the steel cord. Details of S6 will be described hereinafter. In the first loop of the S4 loop, S7 is not processed but is skipped. However, in the second and subsequent loops, the temporary segment of the steel cord detected in the previous loop is coupled with the temporary segment of the steel cord detected in the present loop (S7). A coupling method will be described hereinafter. The line on the right side of the line analyzed in the present loop is set (S8). When the analysis is finished up to the right edge of the X-ray image, the processing routine exits from the S4 loop (S9).

If the coupling length of the temporary segment of the steel cord detected in the S4 loop reaches a predetermined length, such a segment is determined as a steel cord and the coordinate in the right-angled direction among the coordinates of the center of gravity of the coupled object of the temporary segment of the steel cord is set to a representative coordinate of the steel cord in the relevant frame (S10). In S10, the decided number of steel cords and the coordinate in the right-angled direction in the relevant frame of the decided steel cord are output. The processing of the SC detection part 13 is finished.

Subsequently, the processing of S5 will be specifically described. Fig. 5 is a

diagram showing an example of the contrast compensation of the SC detection part 13. (a) in Fig. 5 shows luminance distribution on a certain line in the right-angled direction of the handrail X-ray image by the obtainment of the frame obtaining part 12. An axis in the upper/lower direction of the drawing indicates the coordinate in the handrail right-angled direction and an axis in the left direction of the drawing indicates the luminance. The luminance distribution becomes a valley at the position of the steel cord and becomes a mountain between the steel cords. There are small mountains and valleys in the luminance distribution due to the random noises of the luminance accompanied by the X-ray photographing. Further, the luminance at a position near each of the upper and lower edges of the drawing is low and a contrast of the mountain and valley is low. By performing the smoothing and the contrast compensation to them (S5), the mountains and valleys which are caused by the steel cords are visualized.

(b) in Fig. 5 shows luminance distribution obtained by performing the smoothing processing to the luminance distribution of (a) in Fig. 5. The smoothing can be realized by an averaging filter. As mentioned above, if the averaging filter of such a large size that the mountains and valleys caused by the steel cords are not extinguished is used, the random noises can be preferably eliminated. If parameters of an image pickup system such as a lens and the like of the camera 7 are specified, since the number of pixels on the image of the steel cord to be detected is substantially determined, the proper size of the averaging filter can be predetermined. In portions near the upper and lower edges of the drawing corresponding to the peripheral portions of the handrail, since the luminance and the contrast of the mountains and valleys are low, they are compensated. (c) in Fig. 5 shows projection luminance distribution in the longer direction by S1. A broken line 21 indicates an envelope of the maximum value of the projection luminance distribution in the longer direction. After a primary difference of the luminance distribution was calculated and a plurality of maximum values were detected as values near a zero-crossing, a curve which is come into contact with those plurality of maximum values can be obtained by, for example, a Lagrange's polynomial approximation. If the broken line 21 obtained in this manner is assumed to be $f(x)$ and smoothed luminance distribution (b) is multiplied by, for example, $CONST/f(x)$, the luminance distribution in which the contrast has been compensated is obtained ((d) of Fig. 5). "x" denotes a coordinate in the right-angled direction and CONST is a constant. When a luminance value of the image or a luminance distribution value lies within a range from 0 to 255, a value about 200 is a proper value of CONST. Since the broken line 21 serving as a value of $f(x)$ is used for a division, it is also effective to clip such a value so as not to be equal to a small value, for example, a numerical value of 10 or less so that it does not become unstable. The clipping in this case is such a

processing that if a numerical value of 10 or less appears, it is replaced by a numerical value of 11 or the like that is larger than a lower limit. (d) in Fig. 5 shows the luminance distribution obtained by performing the contrast compensation to the luminance distribution of (b) in Fig. 5 and there are 18 steep valleys. They correspond to the 18 steel cords. If such steep valleys
5 can be caused, a portion where this distribution is primary-differentiated and zero-crossing occurs can be set as a temporary segment of the steel cord.

Subsequently, a detection S6 of the temporary segment of the steel cord (SC) and a coupling S7 of the temporary segment of the steel cord will be specifically explained. Fig. 6 is a diagram showing an example of the detection (S6) of the temporary segment of the steel cord
10 of the SC detection part 13. (a) in Fig. 6 shows contrast-compensated luminance distribution in a manner similar to (d) in Fig. 5. (b) in Fig. 6 shows distribution obtained by primary-differentiating it in the right-angled direction. Although the primary difference is a processing for setting a subtraction value of the luminance value in a lower portion of a point of interest and the luminance value in an upper portion thereof into a value of the point of interest. However,
15 it is necessary to previously and properly adjust a distance (the number of pixels) between the point of interest and each of the upper and lower positions. In the case where a thickness of steel cord to be detected has almost been predetermined as in the case of the invention, the adjusted distance can be held as a fixed value. As a positive threshold value 22 and a negative threshold value 23, adjusted proper values can be also fixed and held.

For example, as for a portion corresponding to a valley 24 of the luminance
20 distribution in (a) in Fig. 6, in coordinate intervals in the right-angled direction corresponding to intervals 25 and 26 until the primary difference value in (b) in Fig. 6 increases from the negative threshold value 23 and reaches the positive threshold value 22, it is sufficient to obtain such a coordinate that the minimum value of the luminance distribution in (a) in Fig. 6. As for the
25 steepness of the valley 24, a distance in the right-angled direction between a maximum value 27 and a minimum value 28 is calculated and if it is equal to or less than a predetermined fixed value, such a portion can be selected as a steep valley. The portion selected as a steep valley in this manner is a detecting position of the temporary segment of the steel cord in the luminance distribution in (a) in Fig. 6.

Fig. 7 is a diagram showing a coupling (S7) processing of the temporary segment
30 of the steel cord of the SC detection part 13. (a), (b), (c), and (d) in Fig. 7 are parts of the image serving as a processing target of the SC detection part 13. Hatched regions 29 and 30 indicate steel cords which exist independently. A hatched region 31 shows a state where two steel cords are in contact with each other. A hatched region 32 shows a short steel cord. A broken line

group 33 in the vertical direction of the drawing explicitly shows lines for a luminance distribution analysis which are set in S3 and S8. That is, the luminance distribution is analyzed along those lines and the temporary segment of the steel cord is decided in the valley portion.

In (b) in Fig. 7, a white rectangle 34 existing in the hatched region 29 is one of the
5 temporary segments of the steel cord. Although other rectangles in the hatched region 29 are also the temporary segments of the steel cord, no reference numerals are allocated thereto because the drawing becomes complicated. White rectangles existing in the hatched regions 30 and 32 are also the temporary segments of the steel cord. In the hatched region 31, since no steep valley is caused in the luminance distribution due to the contact, the temporary segment of
10 the steel cord cannot be set. A fact that the temporary segment of the steel cord cannot be set denotes that the steel cords which exist independently without being in contact with each other do not exist.

(c) in Fig. 7 explicitly shows the operation of the processing loop of S4. That is, the processing is sequentially executed from the left edge to the right edge in order of lines
15 33a, ..., and 33d for a luminance distribution analysis. The set temporary segment of the steel cord is shown by a white rectangle. The temporary segment of the steel cord in which although it is not set yet, it is set after completion of the processing is shown by a broken line. In S7, the temporary segment of the steel cord which was set in the previous line and the temporary segment of the steel cord which was set in the present line are coupled. In this instance, the
20 temporary segments of the steel cords in which the distance is smallest are coupled. The distance is a difference between the coordinates in the right-angled direction of the temporary segments of the steel cords. If an upper limit of the distance in which the temporary segments of the steel cords can be coupled is predetermined, an erroneous coupling can be prevented.

Solid lines 34, 35, and 36 in (d) in Fig. 7 explicitly show results in which the
25 temporary segments of the steel cords were coupled in S7. This means that the independent long steel cords 34 and 35 and the short steel cord 36 exist in the relevant frame.

In S10, a threshold value of the length is preliminarily determined. The coupling results of a predetermined length or more are determined as steel cords and the coupling results less than the threshold value are eliminated. As for the handrail X-ray image by the obtainment
30 of the frame obtaining part 12, since the image size in the longer direction is decided at a point of time when the X-ray photographing unit 1 is designed, the threshold value of the length can be determined.

Although the example in which the smoothing and the contrast compensation are performed each time one line is analyzed in the HR processing loop S4 has been described

above, it is also possible to construct in such a manner that after the smoothing and the contrast compensation were performed as a two-dimensional image processing (S15), the luminance distribution of each line is analyzed as will be described hereinbelow in a processing flow of the second example of the SC detection part shown in Fig. 8. In Fig. 8, processings of S1 and S2 are similar to the processings described in Fig. 4. In S15, a two-dimensional smoothing filter is applied in the handrail X-ray image by the obtainment of the frame obtaining part 12 and the luminance random noises accompanied by the X-ray photographing are set off. The smoothing can be realized by the well-known 2-dimensional smoothing filter. In the contrast compensation, pixels in the X-ray image are multiplied by $CONST/f(x)$ by using the contrast compensation curve $f(x)$ obtained in S2. At this time, if a pixel value exceeds an upper limit such as 255, the clipping processing for replacing the pixel value by such an upper limit value or the like is executed. The X-ray image in which the smoothing and the contrast compensation were performed is formed in S15 by using the above-described method.

In S3 and S4, a luminance distribution analysis is performed while the luminance distribution is skipped from the left edge to the right edge of the X-ray image one line by line or every predetermined lines in a manner similar to the processing described in Fig. 4. The luminance distribution which is obtained here is the luminance distribution which is obtained in S5 in Fig. 4, that is, it is equivalent to that in (d) in Fig. 5. Subsequent processings of S6 to S10 are the same as those in the processing flow described in Fig. 4.

[SC model holding part]

Fig. 9 is a diagram showing a collation method of an SC model and a detected steel cord. Subsequently, the collation method of the SC model and the detected steel cord which is executed by a cooperation processing of the SC model holding part 14 and the SC trace/segment feature detection part 15 will be described with reference to Fig. 9.

To simplify the explanation, it is assumed that the number of steel cords built in the handrail is inherently equal to 5. Therefore, the SC model is also constructed by five steel cords and can be sequentially labeled by "01 cord", "02 cord", "03 cord", "04 cord", and "05 cord" from the edge, respectively. It is now assumed that five steel cords were detected by the SC detection part 13. In this case, the detected steel cords and the steel cords of the SC model are unconditionally made to correspond to each other in order from the edge ((a) in Fig. 9). That is, the detected steel cords 37, 38, 39, 40, and 41 are made to correspond to "01 cord", "02 cord", "03 cord", "04 cord", and "05 cord" of the steel cord model, respectively. By this processing, the names of "01 cord" to "05 cord" are determined for the detected steel cords, respectively. Each cord of the SC model has position information (coordinate). The

coordinates of the SC model are updated by the coordinate of the center of gravity representing the position of the steel cord which was detected and was made to correspond. A white circle at the center of a detected steel cord in (a) in Fig. 9 explicitly shows the position of each center of gravity.

5 (b) in Fig. 9 is a case where three steel cords were detected. It corresponds to a case where other two steel cords are lacking or cannot be detected as two independent steel cords because they are in contact with each other. If such a restricting condition that the order of the upper and lower steel cords of the SC model is not exchanged is set, the cords in which a detected steel cord 42 is made to correspond to the SC model are "01 cord", "02 cord", and "03
10 cord". If it is made to correspond to "04 cord", one of detected steel cords 43 and 44 remains. By the similar restricting condition, the cords in which the detected steel cord 43 is made to correspond to the SC model are "02 cord", "03 cord", and "04 cord". The detected steel cord 44 is made to correspond to "03 cord", "04 cord", and "05 cord".

A distance table in (c) in Fig. 9 shows the conditions as mentioned above. A
15 vertical column of the left edge indicates the cord names of the SC model. The first row at the upper edge shows the steel cords detected in the present frame and they are written from the left to the right in order from the steel cord in which the detected coordinate is small. In this example, the detected steel cords 42, 43, and 44 are written in order from the left. Since which one of the steel cords has been lost is obscure at this point of time, the names cannot be decided
20 to the detected steel cords. In the distance table, an absolute value of a difference between the held coordinate of the model and the coordinate of each of the detected steel cords is written at a position where the row crosses the vertical column. A combination with asterisks is an impossible combination in consideration of the foregoing restricting conditions. Other positions, that is, d11, d21, d31, d22, d32, d42, d33, d43, and d53 denote absolute values of the
25 coordinate differences. A vertical column of the right edge of the distance table is a column where the minimum coordinate difference as a minimum value of the coordinate differences is written. With respect to "01 cord" and "05 cord", since there are only the values of d11 and d53, they are written. In other positions, the minimum value of the relevant row is written. For example, a smaller one of d21 and d22 is written in the row of "02 cord". If both of them
30 are equal, the equal numerical value is written.

Since three steel cords are detected for the five steel cords of the SC model here, any two of them are not detected yet. Therefore, two steel cords are selected in order from the larger value in the vertical column of the right edge of the distance table. The steel cords corresponding to the selected row are regarded as cords which are not detected yet. For

example, if the row of "02 cord" and the row of "03 cord" were selected, "02 cord" and "03 cord" are not detected yet. Thus, the detected steel cord 42 is made to correspond to "01 cord" of the SC model and it is determined that it is "01 cord". The detected steel cord 43 is made to correspond to "04 cord" of the SC model and it is determined that it is "04 cord". The detected
5 steel cord 44 is made to correspond to "05 cord" of the SC model and it is determined that it is "05 cord".

By the above processings, the names of the detected steel cords are determined. On the other hand, the coordinate of "01 cord" of the SC model is updated by the coordinate held by the steel cord 42. The coordinate of "04 cord" of the SC model is updated by the coordinate
10 held by the steel cord 43. The coordinate of "05 cord" of the SC model is updated by the coordinate held by the steel cord 44. The steel cords "02" and "03" of the SC model are updated by the coordinates which are divided internally into 1 : 2 and 2 : 1 between the coordinates of "01" and "04", respectively.

The above-described processings are executed in accordance with a flow for
15 processings of Fig. 10. Fig. 10 is a diagram showing a flow for processings of the SC model holding part 14 and the SC trace/segment feature detection part 15. If the number of detected steel cords is equal to the number on design of steel cords built in the handrail, it is regarded that all of the steel cords were detected, S21 is executed, and this processing routine is finished. In S21, the information of all of the detected steel cords of the SC model is sequentially allocated to
20 the steel cords of the SC model in which a numerical value of the cord name of the steel cord of the SC model is small in order from the steel cord in which the coordinate of the detected steel cord is small. The steel cord information of the SC model denotes the coordinate of the corresponding steel cord and the luminance of the original image at this coordinate position, that is, the luminance of the handrail X-ray image by the obtainment of the frame obtaining part 12.
25 It is a luminance value of the corresponding steel cord portion. The luminances at the positions on both sides of such a region which are away from each other by a predetermined distance are held as background luminances. The predetermined distance denotes a middle point between the coordinates of the adjacent steel cords. In S21, those coordinate values and luminance values are updated.

30 If the number of detected steel cords lacks, the processing routine advances to a processing P1 (S20). In the processing P1, with respect to the present SC model and the detected steel cords, the distance table described in (c) in Fig. 9 is formed (S22). As described above, on the basis of the minimum coordinate difference, the steel cords which are not detected yet are specified and the cord names are allocated to the detected steel cords (S23). On the

basis of the coordinate of the detected steel cords, the coordinates of the SC model are updated (S24). At this time, the luminance values are not updated.

The trace of the steel cords and the updating of the SC model by the cooperation processing of the SC model holding part 14 and the SC trace/segment feature detection part 15 have been described above. The trace is performed by the SC trace part (SC trace unit) in the SC trace/segment feature detection part 15. In the description so far, a case where the steel cords of the number larger than the design number of steel cords were detected is not explained. This is because since the smoothing processing and the like were sufficiently executed in the SC detection part 13 so as not to detect false steel cords, there is no case where many steel cords are detected.

[Segment feature detection method]

Subsequently, a detection method of segment features regarding the light damage of the steel cords which is executed in the SC trace/segment feature detection part 15 will be described. The detection is performed by the segment feature detection part (segment feature detection unit) in the SC trace/segment feature detection part 15. The segment feature is an external appearance feature regarding the light damage which is recognized in the relevant frame and includes a lack of steel cord and a contact between the steel cords. The contact is not limited to the contact between the neighboring steel cords but in the case where the neighboring steel cords or three or more steel cords are in contact with each other, the segment feature is an entanglement feature.

Fig. 11 is a diagram showing a detection method of the segment feature "lack" in the SC trace/segment feature detection part 15. In Fig. 11, a rectangle 45 having sixteen black lateral fringes is a conceptual diagram of the handrail X-ray image. The 16 black lateral fringes indicate the 16 steel cords which exist independently and are detected by the SC detection part 13. Laterally long rectangles in a region surrounded by a broken line 46 indicate the detected steel cords. Eighteen horizontal line segments 47 indicate positions of the coordinates of the steel cords of the SC model held in the SC model holding part 14 and correspond to "01 cord", "02 cord", ..., and "18 cord" in order from the upper cord. The sixteen detected steel cords 46 have already been labeled by the cooperation processing of the SC model holding part 14 and the SC trace/segment feature detection part 15. In the case of this example, the steel cords of "09 cord" and "10 cord" are not detected yet. The coordinates where the steel cords which are not detected yet should exist can be known from the SC model and they are located in a region surrounded by a broken line 48.

Therefore, the lowest luminance of the region shown by the broken line 48 in the

X-ray image is calculated. When it is larger than a predetermined threshold value, it is judged that the steel cord is lacking. As a predetermined threshold value, an average value of the luminance of the corresponding steel cord of the SC model and the luminance of the background adjacent thereto can be used. In the case of this example, an average value of "09 cord" and "10 cord" of the SC model is set as a luminance of the SC model. The luminance at the coordinate of the middle point of the coordinates of the "09 steel cord" and the "10 steel cord" is set as a background luminance of the SC model. An average value of the steel cord luminance and the background luminance is set to the predetermined value and is used as a judgement threshold value adapted to judge whether or not the steel cord is lacking. As mentioned above, the luminance of each of "01 cord" to "18 cord" of the SC model and background luminance among them are equal to the values updated in the frame at which all of the steel cords were detected. In the case where the steel cord is lacking at the position where the steel cord should be independently detected and the luminance is high, it is possible to judge that the steel cord is lacking. By the above-described processings, the lack of steel cord can be detected in the frame.

Fig. 12 is a diagram showing a detection method of a segment "contact" in the SC trace/segment feature detection part 15. In Fig. 12, a rectangle 49 having seventeen black lateral fringes is a conceptual diagram of the handrail X-ray image. A steel cord existing in a region surrounded by a broken line 52 is a steel cord having a thick external appearance due to the contact. Other 16 black lateral fringes indicate the 16 steel cords which exist independently and are detected by the SC detection part 13. The detected steel cords are illustrated in a laterally long rectangle surrounded by a broken line 50. The steel cord having the thick external appearance as shown in the region surrounded by the broken line 52 cannot be detected because a steep valley does not appear in the luminance distribution as described in the SC detection part 13. Eighteen horizontal line segments 51 indicate positions of the coordinates of the steel cords of the SC model held in the SC model holding part 14 and correspond to "01 cord", "02 cord", ..., and "18 cord" in order from the upper cord. The 16 detected steel cords 50 have already been labeled by the cooperation processing of the SC model holding part 14 and the SC trace/segment feature detection part 15 described above. In the case of this example, the steel cords of "09 cord" and "10 cord" are not detected yet. The coordinates where the steel cords which are not detected yet should exist can be known from the SC model and they are located in the region surrounded by the broken line 52.

Therefore, the lowest luminance of the region shown by the broken line 52 in the X-ray image is calculated. When it is smaller than a predetermined threshold value, it is judged

that a plurality of steel cords are in contact with each other. As a predetermined threshold value, an average value of the luminance of the corresponding steel cord of the SC model and the luminance of the background adjacent thereto can be used as described above. In this example, since the steel cords of "09 cord" and "10 cord" are not detected yet, it is judged that those steel
5 cords are in contact with each other. A fact that the steel cord is lacking and the luminance is low at a place where the steel cords should be independently detected denotes that it is possible to judge that a plurality of steel cords are in contact with each other. By the processings as described above, the contact between the steel cords is detected in the relevant frame.

Fig. 13 is a diagram showing a detection method of a segment "entanglement" in
10 the SC trace/segment feature detection part 15. In Fig. 13, a rectangle 53 having sixteen black lateral fringes is a conceptual diagram of the handrail X-ray image. A steel cord existing in a region surrounded by a broken line 56 is a steel cord having a thick external appearance due to the entanglement. Other fifteen black lateral fringes indicate the 15 steel cords which exist
15 independently and are detected by the SC detection part 13. The detected steel cords are illustrated in a laterally long rectangle surrounded by a broken line 54. The steel cord having the thick external appearance as shown in the region surrounded by the broken line 56 cannot be detected because a steep valley does not appear in the luminance distribution as already described above. Eighteen horizontal line segments 55 indicate positions of the coordinates of the steel cords of the SC model held in the SC model holding part 14 and correspond to "01
20 cord", "02 cord", ..., and "18 cord" in order from the upper cord. The fifteen detected steel cords 54 have already been labeled by the cooperation processing of the SC model holding part 14 and the SC trace/segment feature detection part 15 described above. In the case of this example, the steel cords of "08 cord", "09 cord", and "10 cord" are not detected yet. The coordinates where the steel cords which are not detected yet should exist can be known from the
25 SC model and they are located in the region surrounded by the broken line 56.

Therefore, the lowest luminance of the region shown by the broken line 56 in the X-ray image is calculated. When it is smaller than a predetermined threshold value, it is judged that a plurality of steel cords are in contact with each other. As a predetermined threshold value, an average value of the luminance of the corresponding steel cord of the SC model and the
30 luminance of the background adjacent thereto can be used as described above. In this example, since the steel cords of "08 cord", "09 cord", and "10 cord" are not detected yet, it is judged that those steel cords are in contact with each other. In this case, three or more steel cords are in contact with each other and, accordingly, the steel cords other than the neighboring steel cords are also in contact with each other, so that it is judged that the entanglement occurred.

In order to judge the presence or absence of the lack, contact, and entanglement of the steel cords and to refer to the luminance of the region shown by the broken line 48, the luminance of the region shown by the broken line 52, and the luminance of the region shown by the broken line 56, the lowest luminance of the relevant region in the X-ray image has been used.

5 However, in place of it, the lowest luminance of the relevant region in the smoothed image obtained by the SC detection part 13 may be used. By constructing as mentioned above, the apparatus is not subjected to an influence of the variation in luminance upon X-ray photographing.

By the above-described processings, the lack, contact, and entanglement of the
10 steel cords are detected in the frame. Each time the frame processing is executed, in the frame, the presence or absence of the segment feature such as lack, contact, or entanglement is held as a history every feature and updated. Such a segment feature history is called "SC segment feature log in each frame" and it is an output of the SC trace/segment feature detection part 15. An updating history of the coordinates of each steel cord of the SC model described above can
15 be also updated and held every frame. The updating history of the coordinate of each steel cord of the SC model is called "SC trace log in each frame" and it is an output of the SC trace/segment feature detection part 15.

[Quality judgement part in every frame]

Fig. 14 is a diagram showing a quality judgement or graded quality evaluation
20 condition in the quality judgement part 16 in every frame. Subsequently, the quality judgement part 16 in every frame will be described with reference to Fig. 14. The quality judgement part 16 in every frame judges the quality of the steel cords built in the handrail serving as an inspection target or performs a graded evaluation of the quality of the handrail, updates a history in each frame of the quality judgement or the graded evaluation, and holds it. Such a history in
25 each frame is called "quality judgement log in every frame" and it is an output of the quality judgement part 16 in every frame.

The quality judgement of the steel cord or the graded quality evaluation is performed by adding a length, as an index, during which the segment feature such as "lack", "contact" or "entanglement" mentioned above continues in the longer direction of the steel cord.
30 For example, as threshold values in the longer direction of "lack", "contact" and "entanglement", predetermined natural numbers of C1, B1, and C2 are decided, respectively. If the segment features continue for a time interval which is equal to or larger than their threshold values, the quality judgement of the relevant steel cord or the graded evaluation is performed. The judgement result or the evaluation result is held in the "quality judgement log in every frame" of

the relevant frame.

Such a judgement or evaluation can be executed as shown in, for example, Fig. 14. In Fig. 14, a quality rank shows a graded evaluation result of A, B, or C. A indicates the best quality and C denotes the most damaged quality. A right vertical column indicates a judgement condition based on the OR and is output as "quality judgement log in every frame" through a logical arithmetic operation in the quality judgement part 16 in every frame. If the evaluation result is none of the B judgement and the C judgement, the A judgement is set.

When the segment feature of "contact" continues for a time interval of the B1 frames or more, the relevant frame is judged as a B rank. By tracing the frame from the present frame to the subsequent frame by (B1-1) frames, the "quality judgement log in every frame" is updated so that all of the frames locating between the relevant frame and the present frame are set to the B judgement. However, if the C judgement has already been recorded for the relevant frame, the "quality judgement log in every frame" is not overwrite-updated for the C judgement. In other words, as shown in the B rank judgement condition, even if the B judgement condition is satisfied, when it also corresponds to the C judgement, the C judgement is set.

When the segment feature of "lack" continues for a time interval of the C1 frames or more, the relevant frame is judged as a C rank. By tracing the frame from the present frame to the subsequent frame by (C1-1) frames, the "quality judgement log in every frame" is updated so that all of the frames locating between the relevant frame and the present frame are set to the C judgement.

Further, when the segment feature of "entanglement" continues for a time interval of the C2 frames or more, the relevant frame is judged as a C rank. By tracing the frame from the present frame to the subsequent frame by (C2-1) frames, the "quality judgement log in every frame" is updated so that all of the frames locating between the relevant frame and the present frame are set to the C judgement.

Although the graded evaluation processing has been described above, for example, if the A judgement is decided to be "good quality" and the other judgements are decided to be "serious damage", the graded evaluation processing can be executed as a quality judgement. Or, it is also possible to construct in such a manner that the A judgement is decided to be "good quality", the C judgement is decided to be "serious damage", the display part 18 is notified of a fact that it is necessary to exchange the handrail, the maintenance worker is allowed to exchange the handrail, the B judgement is decided to be "light damage", and the display part 18 is notified of a fact that the exchange timing of the handrail is approaching. Although predetermined lengths of B1, C1, and C2 are expressed by the frames in Fig. 14, each of them

can be also expressed by a unit of corresponding millimeters. That is, each of B1, C1, and C2 may be set by a desired value of 000 millimeters that is equal to or larger than 10 millimeters.

The processing of the quality judgement part 16 in every frame and the "quality judgement log in every frame" of the handrail have been described above. Although the "quality judgement log in every frame" evaluates the quality of the steel cord in the description so far, since this means, that the quality of the handrail is evaluated, it can be also regarded as a quality of the handrail.

[Final judgement part]

Subsequently, a processing of the final judgement part 17 will be described. The final judgement part 17 executes a processing for making a quality judgement as a sole handrail serving as an inspection target with reference to the "quality judgement log in every frame".

For example, if the judgement positions of B and C do not exist in the "quality judgement log in every frame", this handrail can be decided as an A judgement as a sole handrail. If the C judgement positions of a predetermined number of frames or more exist in the "quality judgement log in every frame", this handrail can be decided as a C judgement as a sole handrail.

If the judgement is none of A and C, this handrail can be decided as a B judgement as a sole handrail. As a simpler example of realizing the final judgement part 17, the worst quality judgement result recorded in the "quality judgement log in every frame" can be evaluated as a sole handrail. It is also possible to construct in such a manner that on the basis of the result of the final judgement part 17, as a quality of the handrail, the A judgement is decided to be "good quality", the C judgement is decided to be "serious damage", the display part 18 is notified of a fact that it is necessary to exchange the handrail, the maintenance worker is allowed to exchange the handrail, the B judgement is decided to be "light damage", and the display part 18 is notified of a fact that the exchange timing of the handrail is approaching. As for the handrail which was judged to be "light damage", it is desirable to inspect it again at an inspection period shorter than

the normal inspection period. The inspection period may be set to a predetermined period such as every month or the like or can be also determined in consideration of one or more of an operating time, the number of circulating times of the handrail, and a movement distance. The processing of the final judgement part 17 has been described above. The embodiment of the construction of the image processing part of the X-ray inspection apparatus of the invention has been described above.

[Flow for processings of image processing part]

Fig. 15 is a diagram showing a flow for processings of the image processing part of the X-ray inspection apparatus of the invention. Subsequently, the flow for the processings of the image processing part will be described with reference to Fig. 15. Prior to newly

processing the image of the handrail, a memory and parameters which are used for the processings are initialized (S25). As a memory initialization, for example, there are initializations of the "SC segment feature log in each frame", "SC trace log in each frame", and "quality judgement log in every frame".

5 In a frame processing loop S26, a loop processing is executed until completion of a moving image processing necessary for quality evaluation of the handrail, and when the processings of all frames to be processed are completed, the processing routine exits from this loop and advances to processings of S33 and subsequent steps (S27). A frame end judgement processing S27 and a frame obtainment processing S28 are executed by the frame obtaining part 10 12. Subsequently, an SC detection processing S29 is executed by the SC detection part 13. An SC trace and segment feature detection processing S30 is executed by the cooperation of the SC model holding part 14 and the SC trace/segment feature detection part 15. At the same time, an SC model updating processing S31 is executed with respect to the SC model held in the SC model holding part 14. Subsequently, a quality judgement processing S32 in every frame is 15 executed with respect to the relevant frame and the "quality judgement log in every frame" is updated. This processing is executed by the quality judgement part 16 in every frame.

After the foregoing processings were completed with respect to all of the necessary frames, a handrail quality final judgement processing S33 is executed by the final judgement part 17. At this time, a final judgement result can be held in a magnetic recording or 20 transmitted to a quality management server or the like through a network. By the foregoing processings, the automatic judgement of the quality evaluation of the handrail is realized. Although processings of S34 to S38 can be also added, they will be described hereinafter. [Second example of image processing part]

By the processing parts and the processing flow described so far, the quality 25 judgement based on "lack", "contact", and "entanglement" of the steel cords can be made. However, at the extremely initial light damage grade, even if the above three kinds of external appearance are not obtained, such a situation that the steel cords are moved in the right-angled direction occurs due to the light damage of the rubber which holds the steel cords. Such a situation is called an "unfixed steel cord" feature in addition to the above three kinds of external 30 appearance feature.

Fig. 16 is a diagram showing a second embodiment of the image processing part of the X-ray inspection apparatus of the invention. The X-ray inspection apparatus shown in Fig. 16 has a construction in which a trace log database 57 and an unfixed steel cord detection part in every frame (unfixed steel cord detection unit in every frame) 58 are added to the X-ray

inspection apparatus shown in Fig. 3. A part 59 of 12 to 15 has substantially the same contents as those of the processings which are executed by the frame obtaining part 12, SC detection part 13, SC model holding part 14, and SC trace/segment feature detection part 15 in Fig. 3.

5 The "SC trace logs in each frame" of the handrail measured in the past have been stored in the trace log database 57. The "SC trace log in each frame" is the history data which was output by the cooperation processing of the SC model holding part 14 and the SC trace/segment feature detection part 15 as already described above.

10 At the same position in the longer direction, the unfixed steel cord detection part 58 in every frame compares the trace log in every frame which was output by the part 59 of 12 to 15 and the trace logs in every frame of the handrail which was output in the past and stored in the trace log database 57 at the time of the handrail measurement. When the trace logs at the same position in the longer direction in the present measurement and the past measurement are compared, if a mark such as a metal or the like which can be photographed by the X-ray is preliminarily marked upon measurement, they can be easily compared. As a comparison result,
15 if the coordinate in the handrail right-angled direction is deviated by a predetermined distance or more (case where the position of the steel cord is deviated from the inherent position (which can be specified by the past measurement) of the steel cord by a predetermined distance or more in the direction at a right angle to the longer direction of the handrail), it is judged that the unfixed steel cord has occurred. A fact that the unfixed steel cord exists in the relevant frame is stored
20 as "position log of unfixed steel cord in every frame" into the memory.

The processing of the quality judgement part 16 in every frame has already been described. Among the frames which were judged to be A, with respect to the frame in which the occurrence of the unfixed steel cord is recognized, the A judgement is replaced by a B plus judgement with reference to the "position log of unfixed steel cord in every frame". Thus, in
25 the foregoing description based on Fig. 14, the quality ranks of the steel cord is classified into four kinds of ranks of A, B plus (B+), B, and C from the three kinds of ranks of A, B, and C. B plus denotes a rank in which although there are no signs of light damage in the external appearance of the steel cord itself, there is a doubt of light damage in the rubber which holds the steel cord. As for the rank of B plus, the final judgement of the final judgement part 17 can be
30 also set into four ranks through the foregoing quality judgement log in every frame. In this case, the final judgement is also classified into four ranks of A, B plus, B, and C. The judgement result of B plus can be also judged to be "light damage" as quality.

[Panorama display]

By the above description, according to the X-ray inspection apparatus for the

handrail of the escalator of the invention, the quality judgement or the multigrade quality judgement of the steel cords built in the escalator handrail (or the handrail itself) is automatically made. In addition to the automatic judgement, if the steel cords are panorama-displayed, such an apparatus becomes an apparatus which is extremely useful for the maintenance of the escalator handrail. Therefore, an embodiment of a panorama creation and display of the X-ray inspection apparatus for the handrail of the escalator of the invention will now be described. A processing for forming the panorama and displaying it to the display part 18 is executed by a panorama display part (panorama display unit) (not shown) provided for the frame obtaining part 12.

In the description of the frame obtaining part 12, it is specifically shown that at the time of the X-ray photographing, if a relative speed of the X-ray photographing unit 1 and the handrail 4 is a predetermined speed, the width of the field of view in the longer direction of the steel cord image photographed in each frame is equal to the predetermined length. A difference between the positions in the longer direction of the steel cords of the neighboring frames is also constant. At the time of the X-ray photographing, even if the relative speed of the X-ray photographing unit 1 and the handrail 4 is a non-stationary speed, by processing the frame each time the handrail 4 is moved by a predetermined distance based on the encoder 3 or by constructing the movies by the frame obtained each time the handrail 4 is moved by the predetermined distance, an image that is equivalent to the image obtained by photographing the handrail which is moving at the predetermined speed can be obtained.

Fig. 17 is a diagram showing a panorama forming processing of the image processing part of the X-ray inspection apparatus of the invention. As mentioned above, it is a processing for forming the panorama image from the moving image obtained at the predetermined speed or obtained at a speed similar to the predetermined speed by using the encoder 3. (a) in Fig. 17 is a conceptual diagram of luminance sampling to form the panorama image. (b) in Fig. 17 is a conceptual diagram for mapping the sampled luminance. An explanation will be made on the assumption that the number of steel cords is equal to 10.

(a) in Fig. 17 shows a state where a group of 10 steel cords is photographed while moving them by a distance of d_0 millimeters in the longer direction each time one frame is photographed. The obtained frames are labeled by $f_0, f_1, f_2, f_3, \dots$. It is assumed that the length of the field of view in the longer direction of the steel cord in each frame is equal to d_0 millimeters. A boundary of the field of view of each frame is shown by a broken line which vertically transverses the steel cords. c_0, c_1, c_2 , and c_3 indicate arrays of the pixels existing at the center of the field of view in the longer direction of the frames f_0, f_1, f_2 , and f_3 , respectively.

cl0 and cr0 indicate arrays of the every seven pixels arranged at regular intervals on the left side and the right side of c0, respectively. Arrays cl1, cr1, cl2, cr2, cl3, and cr3 of every seven pixels are also arranged at regular intervals on the left side and the right side of c1, c2, and c3, respectively.

5 By obtaining the luminance values from the pixels corresponding to those pixel arrays and adjacently arranging those pixel luminance values as illustrated in (b) in Fig. 17, a panorama image of two frames f0 and f1 is formed. The steel cord shown by this panorama image has a length of two frames in the longer direction, that is, a length of $d_0 \times 2$ millimeters. However, a space resolution in the longer direction deteriorates due to the luminance sampling.
10 Although not shown in (b) in Fig. 17, this is true of the frames f2 and f3.

If the luminance sampling of (a) in Fig. 17 and the luminance mapping of (b) in Fig. 17 are performed with respect to all frames of the relevant moving image, a luminance-mapped image becomes a panorama image of the relevant portion of the steel cord. Although the space resolution in the longer direction deteriorates as mentioned above, in the case of
15 visually inspecting the quality of the steel cord, the deterioration in resolution of such an extent does not cause a problem. If the number of arrays of the pixels included in cl0, cr0, cl1, and cr1 is increased in accordance with necessity, the deterioration in resolution can be reduced.

The description has been made above on the assumption that the width of the field of view in the longer direction of each frame is equal to the movement amount d_0 upon
20 photographing. However, actually, the width of the field of view of the frame varies due to a variation on manufacturing of the X-ray tube 5. When the width of the field of view is larger than d_0 due to the variation, the arrays cl0, cr0, cl1, cr1, ... of the pixels are arranged in the regions of the width d_0 around the centers c0, c1, c2, c3, ... of the frames and the luminance sampling is performed from the pixel arrays, a panorama image similar to that mentioned above
25 is obtained. When the width of the field of view of the frame is smaller than d_0 due to the variation, the arrays cl0, cr0, cl1, cr1, cl2, cr2, ... of the pixels for the luminance sampling are arranged around the centers c0, c1, c2, ... in the frames and results of the sampling are mapped as illustrated in (b) in Fig. 17, a panorama image is also obtained. In this case, each interval in the longer direction of the arrays of the pixels of the luminance sampling of cl0, cr0, cl1, cr1, cl2,
30 cr2, ... is smaller than that in each of the above-mentioned two examples, that is, those in the case where the width of the field of view is equal to or larger than d_0 . Thus, a local distortion occurs in the panorama image in (b) in Fig. 17. However, as shown in (b) in Fig. 17, the number D of pixels between c0 and c1 is the same as that in each of the above-mentioned two examples and is reproduced as the same distance in the panorama image. When the panorama

image is constructed by the panorama synthesizing method mentioned above, even if the variation on manufacturing of each X-ray tube exists in the width of the field of view of the frame, since the distortion that is caused by the variation is uniformly distributed to the whole panorama image, the panorama image in which the escalator maintenance person does not

5 erroneously judge upon visual inspection can be provided.

When the panorama image as described above is displayed, the quality judgement result held in the "quality judgement log in every frame" which has already been described in Figs. 3 and 16 can be displayed, for example, per color in an upper portion of the relevant panorama image frame. When a display area of the display part 18 of the image processing part
10 2 is limited, the whole panorama cannot be displayed. In such a case, the longer direction of the whole panorama is properly reduced and displayed and a part thereof is not reduced or is displayed at a reduction degree smaller than the whole panorama image, so that the panorama image can be effectively displayed in the limited display screen.

An example of the panorama display is shown in Fig. 18. A handrail number 61
15 for specifying the handrail serving as an inspection target, a final judgement result 62, a whole panorama 67 which is reduced and displayed, and a part 66 of the panorama are displayed in a panorama display screen 60 displayed on the display part 18. A rectangle 68 is a portion of the whole panorama 67 and shows a portion displayed as a part 66 of the panorama. When the rectangle 68 is moved, for example, to the right and left by the key operation, the portion which
20 is displayed in the part 66 of the panorama which is displayed also changes in association with the operation. In this manner, both of the whole panorama image and a part of the whole panorama image are displayed and the whole panorama image is displayed at a magnification smaller than that of a part of the whole panorama image. A band 63 in the longer direction is a portion where the results of the quality judgement (corresponding to the grade of quality of the
25 steel cord or handrail) held in the "quality judgement log in every frame" are displayed so as to be distinguished by the colors, symbols, or a difference of textures in correspondence to the position in the longer direction of the steel cord. For example, they can be displayed in such a manner that lattice regions 64 and 65 indicate the C rank, a hatched region 70 indicates the B rank, and other regions indicate the A rank.

30 Subsequently, with respect to a flow for processings of the image processing part 2 of the X-ray inspection apparatus of the invention, S34 to S38 in Fig. 15 will be described. In S34, the panorama display part superimposes the final judgement result into the panorama image described in Fig. 18 and displays the obtained panorama image onto the display part 18. A part 66 of the panorama which is displayed without being reduced may be displayed so that the frame

portion of the rank in which a degree of light damage is largest is preferentially selected with reference to the "quality judgement log in every frame". When the whole range indicates the A rank, the portion where the segment feature occurred may be selected as a display portion with reference to the "SC segment feature log in each frame". Upon displaying, the image may be

5 stored into a magnetic disk.

In a state where the panorama image is displayed in S34, the panorama display part enters a display processing loop S35 and receives a key input by the command input part 19 (S36). By the key input, the rectangle 68 in Fig. 18 is moved to the right and left and, on the basis of information thereof, a portion which is displayed as a panorama 66 can be updated and
10 displayed (S38). At this time, when the same key as the judgement rank (quality of the handrail) by the final judgement part 17 is inputted, it is judged that a correct end key has been inputted. The processing routine exits from the display processing loop S35. All of the processings of the inspection apparatus for the handrail of the passenger conveyer of the invention are finished. By finishing all of the processings by the same key input as the
15 judgement result of the inspection apparatus for the handrail of the passenger conveyer of the invention as mentioned above, such a situation that the escalator maintenance person finishes the inspection without confirming can be prevented.

According to the invention, as well as a case of one or two steel cords, even in a case where three or more steel cords are built in the handrail, the presence or absence of the
20 unfixed steel cord, the lack of the steel cord, the contact between the steel cords, or the entanglement of the steel cords is detected, they are quantitatively measured by using the lengths in which those external appearance features continue, and the degree of light damage of the steel cord can be judged step by step at three or more grades from a sole or a combination of them. According to the invention, since the processing for accessing the pixels of the X-ray image at
25 random in accordance with the pattern of the X-ray image is unnecessary, the high speed processing can be completed or, even in a low-price handy type PC, the processing can be completed within a permissible time.

Although the invention has been described above with respect to the embodiments, the constructions described in the embodiments so far are merely examples and
30 many modifications of the invention are possible within the scope of the invention without departing from the technical idea. The constructions described in the embodiments may be combined and used so long as they are not contradictory. In the Description, there is also a case where "inspection" is called "check" and it is assumed that "inspection" in the Description and claims incorporates "check". Similarly, in the Description, there is also a case where

"maintenance" is called "repair" and it is assumed that "maintenance" in the Description and claims incorporates "repair". The maintenance (repair) denotes that at least one of the inspection (check), mending, and exchange is executed. It incorporates a case where two or more of them are combined and executed.

CLAIMS:

1. An inspection apparatus for a handrail of a passenger conveyer, comprising:
an X-ray photographing unit (1) for photographing the handrail (4) of the passenger conveyer by an X-ray; and
an image processing unit (2) for processing an image photographed by said X-ray photographing unit (1), detecting a lack or entanglement of steel cords built in said handrail (4), and judging that quality of said handrail (4) is "serious damage" in the case where a length of the lack or entanglement of said steel cords in a longer direction of said handrail continues by a predetermined length or more.
2. The apparatus according to claim 1, wherein said image processing unit (2) detects a contact between said steel cords and judges that the quality of said handrail (4) is "light damage" in the case where both of the lengths of the lack and entanglement of said steel cords in the longer direction of said handrail (4) are shorter than the predetermined length and a length of the contact between said steel cords in the longer direction of said handrail continues by the predetermined length or more.
3. The apparatus according to claim 2, wherein said image processing unit (2) judges that the quality of said handrail (4) is "good quality" in the case where all of the lengths of the lack, entanglement, and contact of said steel cords in the longer direction of said handrail (4) are shorter than the predetermined length.
4. The apparatus according to claim 2, wherein said image processing unit (2) detects the unfixed steel cord in which a position of said steel cord is deviated from an inherent position of said steel cord by a predetermined distance or more in the direction at a right angle to the longer direction of said handrail (4), and judges that the quality of said handrail (4) is "light damage" in the case where the length of the lack or entanglement of the steel cords in the longer direction of said handrail is shorter than the predetermined length and the unfixed steel cord has occurred.
5. The apparatus according to claim 4, wherein said image processing unit (2) judges that the quality of said handrail (4) is "good quality" in the case where all of the lengths of the lack, entanglement, and contact of the steel cords in the longer direction of said handrail (4) are shorter than the predetermined length and the unfixed steel cord does not occur.
6. The apparatus according to claim 1, wherein said image processing unit (2) has:
a steel cord detection unit (13) for detecting the steel cords which exist independently among said steel cords; and
a segment feature detection unit (15) for detecting that the contact, entanglement,

or lack has occurred in said steel cords in a region where said steel cord detection unit (13) cannot detect the steel cords.

7. The apparatus according to claim 6, wherein said segment feature detection unit (15) judges that the contact or entanglement has occurred in said steel cords in the region where said steel cords cannot be detected in the case where said region is darker than a predetermined first luminance threshold value, and detects that the lack has occurred in said steel cords in the case where said region is brighter than a predetermined second luminance threshold value.

8. The apparatus according to claim 1, wherein said image processing unit (2) has a segment feature detection unit (15) for tracing said steel cords and detecting that the unfixed steel cord, contact, entanglement, or lack has occurred in said steel cords.

9. The apparatus according to claim 8, wherein said image processing unit (2) has:
a trace log database (57) for holding a trace result of said steel cords which were measured in the past; and

an unfixed steel cord detection unit (58) for comparing the trace result of said steel cords and a trace result of the same handrail held in said trace log database (57) and detecting that the unfixed steel cord has occurred in said steel cord in the case where a difference of a predetermined distance or more exists in a coordinate of said steel cord in a direction at a right angle to the longer direction of said handrail (4).

10. The apparatus according to claim 8, wherein said image processing unit (2) has:
a steel cord trace unit (15) for tracing said steel cords with reference to a steel cord model; and

a steel cord model holding unit (14) for updating and holding position information of the steel cords of said steel cord model and luminance information of a steel cord portion and a background portion.

11. The apparatus according to claim 1, further comprising a panorama display unit (18) for forming a panorama image of said steel cords from the image photographed by said X-ray photographing unit (1), superimposing the presence or absence of an unfixed steel cord, a contact, the entanglement, or the lack in each position in the longer direction of said steel cords to said panorama image, displaying the obtained panorama image, and displaying ranks of quality of said handrail (4) by said image processing unit (2) in each position in the longer direction of said steel cord so that said ranks can be distinguished by colors, symbols, or textures.

12. The apparatus according to claim 11, wherein said panorama display unit (18) displays a whole portion of said panorama image and a part of said whole panorama image into one display screen, displays said whole panorama image at a magnification smaller than that of a

part of said whole panorama image, and preferentially selects and displays a location where the unfixed steel cord, contact, entanglement, or the lack exists in said steel cords as a part in said whole panorama image.

13. The apparatus according to claim 11, further comprising a command input unit (19) which can finish the display of said panorama image only when a same result as the quality of said handrail (4) by said image processing unit (2) is inputted.

14. A maintenance method of a passenger conveyer, comprising the steps of:
photographing a handrail (4) of the passenger conveyer by an X-ray; and
processing an image photographed by said X-ray, detecting a lack or entanglement of steel cords built in said handrail (4), and judging that quality of said handrail (4) is "serious damage" in the case where a length of the lack or entanglement of said steel cords in a longer direction of said handrail continues by a predetermined length or more.

15. The method according to claim 14, wherein a contact between said steel cords is detected and in the case where both of the lengths of the lack and entanglement of said steel cords in the longer direction of said handrail (4) are shorter than the predetermined length and a length of the contact between said steel cords in the longer direction of said handrail continues by the predetermined length or more, it is judged that the quality of said handrail (4) is "light damage".

16. The method according to claim 15, wherein in the case where all of the lengths of the lack, entanglement, and contact of said steel cords in the longer direction of said handrail (4) are shorter than the predetermined length, it is judged that the quality of said handrail is "good quality".

17. The method according to claim 15, wherein the unfixed steel cord in which a position of said steel cord is deviated from an inherent position of said steel cord by a predetermined distance or more in the direction at a right angle to the longer direction of said handrail (4) is detected, and in the case where the length of the lack or entanglement of the steel cords in the longer direction of said handrail is shorter than the predetermined length and the unfixed steel cord has occurred, it is judged that the quality of said handrail (4) is "light damage".

18. The method according to claim 17, wherein in the case where all of the lengths of the lack, entanglement, and contact of the steel cords in the longer direction of said handrail (4) are shorter than the predetermined length and the unfixed steel cord does not occur, it is judged that the quality of said handrail (4) is "good quality".

19. The method according to claim 14, wherein if it is judged that the quality of said

handrail (4) is "serious damage", said handrail is mended, exchanged, or exchanged after it was mended.

20. The method according to claim 15, wherein if it is judged that the quality of said handrail (4) is "light damage", the handrail which was judged to be "light damage" is inspected again at a period shorter than a normal inspection period.