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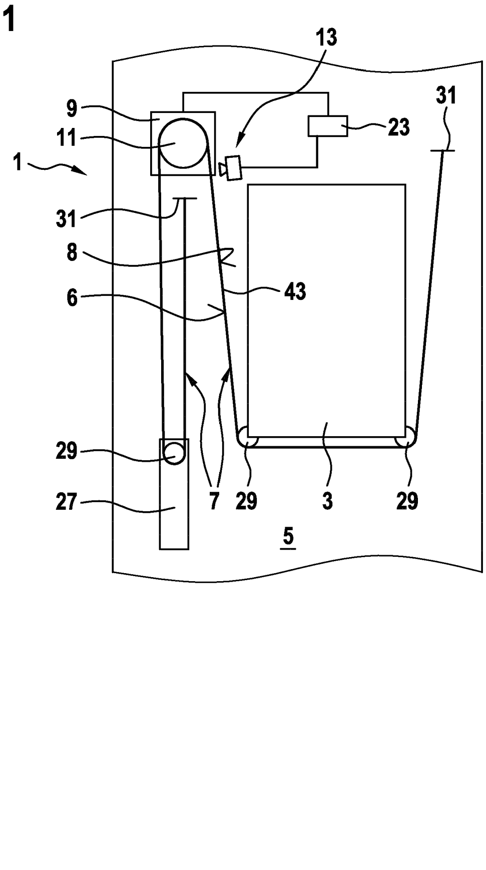
(54) ELEVATOR ARRANGEMENT WITH A CAMERA FOR VISUAL INSPECTION OF A SUSPENSION TRACTION MEMBER

(57) An elevator assembly (1) is proposed to comprise an elevator car (3), a suspension traction member (7) suspending the elevator car (3), a drive engine (9) driving a traction sheave (11) for displacing the suspension traction member (7) running along a traction surface of the traction sheave (11), a camera (15) and an image processing unit (17). Therein, the camera (15) is directed towards the suspension traction member (7) for acquiring images of a surface (6, 8) of the suspension traction member (7) during a monitoring procedure for monitoring a deterioration state of the suspension traction member (7). Furthermore, the image processing unit (17) is adapted for processing and analysing the images acquired by the camera (15) during the monitoring procedure for detecting visual deteriorations of the suspension traction member (7) and for generating a signal upon detection of such visual deteriorations. Therein, the camera (15) and the image processing unit (17) are adapted for, during the monitoring procedure, acquiring and processing images of a focus area (18) in predetermined time intervals such as to acquire images of non-consecutive regions of the surface (6, 8) of the suspension traction member (7) while the suspension traction member (17) moves through the focus area (18).

Using the camera (15) and the image processing unit (17), deteriorations of the suspension traction member (7) resulting in changes in its visual appearance may be detected and measures e.g. for increasing safety of the elevator assembly (1) may be initiated correspondingly.

Fig. 1



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Description

[0001] The present invention relates to an elevator assembly. Particularly, the present invention relates to an approach for monitoring an integrity of a suspension traction member (STM) in an elevator assembly.

[0002] An elevator serves for transporting people or goods within a building, typically in a vertical direction. An elevator car accommodating the people or goods may be displaced within an elevator shaft. Therein, the elevator car is generally suspended by a suspension traction member typically comprising several load carrying ropes or belts. In most cases, the ropes or belts comprise load-carrying cords which are included in an overcoat, sheath or envelope of an elastomer material such as rubber or silicone. On the one hand, the suspension traction member may suspend the loads of the elevator car. On the other hand, the suspension traction member may be displaced using a drive engine with a traction sheave cooperating with the suspension traction member in order to thereby displace the suspended elevator car within the elevator shaft. In most cases, the suspension traction member also suspends a counterweight.

[0003] An integrity of the ropes or belts of the suspension traction member is critical for a safe operation of the elevator assembly. Therefore, such integrity is to be monitored and various deteriorations or failures of the suspension traction member are to be detected with a high degree of reliability. Such deteriorations or failures comprise, inter-alia, broken or cracked cords or strands of the suspension traction member, local cracks or abrasion in the overcoat enclosing the cords, damages caused by corrosion or fretting corrosion, a presence of contaminants on a surface of the suspension traction member, etc. Therein, "deterioration" or "failing" shall be interpreted in a broad sense not just meaning any traction member rupture but an inability to fulfil operational requirements of the elevator assembly.

[0004] In former times, such deteriorations or failures in an STM had to be detected by maintenance staff upon periodical inspection of the STM for example on a yearly basis. However, such inspection requires significant labor resulting in high costs. Furthermore, suddenly occurring deteriorations or failures may not be detected for a relatively long time until a next maintenance is executed.

[0005] In recent times, alternative approaches for detecting deteriorations or failures in an STM have been developed. Such approaches allow for example automatic or semi-automatic monitoring of a current deterioration state of the STM. For example, techniques have been proposed that claim to be able to detect small changes in a cross section of the cords embedded in a rubber overcoat of an STM by for example monitoring an electrical impedance or by magnetic flux measurements. Basically, in such approaches, a change of electrical or magnetic conductivity in conductive cords of the STM is identified and is interpreted as signalizing a presence of defects in cords of the STM. Often the electrical impedance measurement is accompanied by a detection of an earth-fault which, in some cases, is able to reveal a presence of damages in the isolating overcoat enclosing the cords.

[0006] Alternatively or additionally, lifetime expectations may be taken into account. Thereby, it may be ensured that the STM may be dismissed before, for example, any rubber material starts to degrade. However, lifetime of an STM is also limited by a number of bending cycles and therefore a trip counter or a more sophisticated bending cycle counter may be employed.

[0007] Such recent approaches for automatic monitoring an integrity of an STM based on electric measurements and/or based on counting bending cycles are presented, inter-alia, in the applicant's international patent application PCT/EP2016/067970, the content of which shall be incorporated herein by reference.

[0008] There may be a need for an elevator assembly in which an integrity of an STM may be supervised in an automatic manner, with high reliability, using relatively simple hardware and/or with low costs associated thereto.

[0009] At least one of such needs may be met with the subject-matter of the independent claim. Advantageous embodiments are defined in the dependent claims and in the following specification.

[0010] According to an aspect of the present invention, an elevator assembly comprising an elevator car, a suspension traction member, a drive engine, a camera and an image processing unit is proposed. The elevator car is displaceable within an elevator shaft. The suspension traction member suspends the elevator car. The drive engine drives a traction sheave for displacing the suspension traction member running along a traction surface of the traction sheave. Therein, the camera is directed towards the suspension traction member for acquiring images of a surface of the suspension traction member during a monitoring procedure for monitoring a deterioration state of the suspension traction member. Furthermore, the image processing unit is adapted for processing and analysing the images acquired by the camera during the monitoring procedure for detecting visual deteriorations of the suspension traction member and for generating a signal upon detection of such visual deteriorations. Therein, the camera and the image processing unit are adapted for, during the monitoring procedure, acquiring and processing images of a focus area in predetermined time intervals such as to acquire images of non-consecutive regions of the surface of the suspension traction member while the suspension traction member moves through the focus area.

[0011] Ideas underlying embodiments of the present invention may be interpreted as being based, inter alia, on the following observations and recognitions.

[0012] As briefly indicated in the above introductory portion, various techniques have been developed for automatically monitoring the integrity of an STM thereby avoiding or at least relaxing requirements for periodic manual inspections of the STM. However, these techniques typically allow detecting only specific types of deteriorations or failures in the STM.

[0013] For example, techniques based on measuring electrical characteristics of cords of the STM may generally reliably indicate an occurrence of ruptures in cords of the STM as such ruptures result in an increased electrical resistance through the cords. Similarly, such measurements may indicate an occurrence of broken cords penetrating through the enclosing polymer overcoat thereby inducing an electric earth-fault upon coming into contact with other components of the elevator assembly such as the traction sheave or pulleys being on an electrical earth potential. There is also a hope that measured changes in electrical characteristics of the cords may be useful for indicating any corrosion at the cords as such corrosion may reduce an effective cross section of the cords which may result in an increased electric resistance of these cords.

[0014] Similarly, counting effective bending cycles of the STM may be used as another or additional measure for determining a deterioration state of the STM. Therein, an allowable over-all number of bending cycles may be assumed based for example on lifetime measurements of the STM.

[0015] However, all these known approaches may typically be used only for detecting specific types of deteriorations or failures whereas other types of deteriorations or failures generally remain undetectable. For example, neither techniques based on electrical measurements nor techniques based on counting bending cycles may allow for reliably detecting for example superficial damages at the elastomer overcoat of the STM which, on a medium or long time range, may induce severe deteriorations at the STM potentially reducing its load bearing capacity. Similarly, depositions of dust or dirt on a surface of the STM may not be detected using the conventional approaches, but such depositions may harm the STM's integrity for example due to abrasion or fretting corrosion. There are several further types of possible damages, deteriorations or failures in STMs which may not be easily detected using the conventional techniques.

[0016] Accordingly, the technique described herein intends to provide an alternative or supplementary approach for detecting at least some of possible damages, deteriorations or failures in an STM. Particularly, the technique described herein may be applied in combination with other conventional monitoring techniques in order to increase an overall spectrum of detecting possible damages, deteriorations or failures in the STM thereby enabling an improved safety level of the elevator assembly.

[0017] The technique described herein mainly relates to visual inspection of a surface of the STM. Therein, visual inspection means that changes or abnormalities of an optical appearance of the monitored surface of the STM may be detected. Such visual inspection shall be performed not by human maintenance staff but using technical means such as to allow at least some degree of automation and/or remote control.

[0018] Accordingly, it is proposed to provide the elevator assembly with a camera and an image processing unit. The camera is a technical device which may acquire 1D or preferably 2D images of an area of interest (herein also referred to as focus area). Therein, the camera should be adapted for acquiring the images with a sufficiently high resolution such that information about any critical changes or abnormalities in the visual appearance of the imaged object is contained in the acquired images. The image processing unit is a technical device which may process the acquired images. Therein, the image processing unit may be adapted for processing and analysing the acquired images in such a manner that the information about the critical changes or abnormalities in the imaged object may be detected. Upon detecting such critical changes or abnormalities, the image processing unit may generate a signal and may transmit this signal to other components of the elevator assembly in order to thereby indicate the detected deterioration or failure of the imaged object.

[0019] Therein, the camera and the image processing unit shall be configured such that, during the monitoring procedure, images of the focus area may be acquired and processed in predetermined time intervals such as to acquire images of non-consecutive regions of the surface of the suspension traction member while the suspension traction member moves through the focus area. In other words, the camera and the image processing unit may acquire images and process acquired images periodically while the STM is gradually displaced through the imaged focus area. Accordingly, a multiplicity of images may be acquired at various locations along the STM. Such locations should preferably be spaced apart from each other such that images are acquired of non-consecutive regions, i.e. the regions imaged during a single run of the suspension traction member do not overlap and do not directly adjoin to each other but there are (significant) spaces between those regions which are imaged during a single run. For example, the spaces between imaged regions may be same or longer than the imaged regions. Alternatively, the spaces between imaged regions may be at least 20%, preferably at least 50%, of the length of the imaged regions.

[0020] In principle, a periodicity with which the images are acquired and processed could be set such that succeeding images represent consecutive areas of the STM which directly adjoin to each other or even overlap each other. In such case, the entire STM could be examined by moving all portions of the STM through the imaged focus area in a single run, i.e. upon moving the elevator cabin only once between its opposite extremum positions. However, as during normal operation of the elevator assembly, the STM is moved through the focus area at high velocities, this may require a high periodicity in image acquisition, i.e. a high frame rate, as well as very fast image processing, both resulting in increased requirements to the camera and the image processing unit.

[0021] However, in order to relieve such requirements and thereby allow for using a less complex camera and/or image processing unit, it may also be accepted to acquire and process images at longer predetermined time intervals. In such case, successively acquired images typically do not represent consecutive portions of the STM which directly adjoin each other but, instead, non-imaged areas of the STM remain between imaged areas of the STM upon a single image acquisition run, i.e. when the STM is moved at high velocity through the focus area only a single time.

[0022] For the specific application in an elevator assembly, the camera may be installed in the elevator assembly such as to be directed towards the STM, i.e. the STM is the imaged object. Accordingly, the camera may acquire images of a surface of the STM to be observed during a monitoring procedure.

[0023] Therein, the camera should be adapted to acquire the images with a sufficiently high spatial resolution such that any critical microscopic deteriorations or damages at the observed surface of the STM are visible in the acquired images. For example, the camera should have a spatial resolution at least in a millimetre range, i.e. structures with a size of more than one or more than a few millimetres should be visible in the acquired images. Preferably, the camera may have a spatial resolution in a 100μm range or even 10μm range such that even very small structures such as microscopic cracks or fissures may be resolved.

[0024] The camera should be adapted for acquiring images of at least a portion of the surface of the observed STM. Preferably, the camera should be adapted for acquiring images including an entire width of for example a belt or rope of the STM. Accordingly, by sequentially displacing the STM through the area imaged by the camera, the camera may provide images covering for example almost the entire length of the surface of the STM directed towards the camera.

[0025] Generally, the camera may be relatively simple and may therefore be of low costs. For example, as a distance between the camera and the imaged area on the surface of the STM is typically constant, the camera may be provided with a fixed focus, i.e. no complicated focusing optics may be needed. For example, the camera may be provided with a one-dimensional or two-dimensional array of light-sensitive electronic sensors such as a CCD or CMOS array sensor. A fixed focus optics comprising for example one or more stationary lenses, mirrors, etc. may be used for imaging a surface of an observed object onto a light-sensitive surface of the sensor. Upon imaging, the sensor may generate a serial or parallel set of electronic signals representing optical characteristics of the imaged surface. These electronic signals may be submitted to the image processing unit.

[0026] Upon receiving such electronic image signals, the image processing unit may process and analyse the signals such as to enable distinguishing intact areas from deteriorated or defective areas of the observed STM. Such image processing and analysing may be based on various techniques. For example, acquired images may be compared with reference images in order to determine any differences for example between an actual imaged surface area of an STM and a reference non-deteriorated surface area of the STM.

[0027] Alternatively or additionally, specific image analysis may be performed using for example optical pattern recognition. Therein, a non-deteriorated pattern on a surface of an imaged STM may be distinguished from a deteriorated pattern thereby indicating some visible deteriorations or failures at the surface of the STM.

[0028] Upon detecting a visual deterioration or failure, the image processing unit may generate a suitable signal. Such signal may be transmitted for example to other components of the elevator assembly in order to inform about the occurrence of a deterioration at the STM and/or to instruct the other components to initiate suitable measures.

[0029] For example, the signal issued by the image processing unit may be transmitted to an elevator control. Upon receiving the signal, the elevator control may stop an elevator operation. Alternatively, the elevator control may modify the elevator operation for example by reducing a displacement velocity and/or reducing an allowable payload.

[0030] Further measures such as issuing a warning signal for informing elevator passengers and/or informing a remote control centre monitoring an operation of the elevator assembly may be initiated.

[0031] According to an embodiment, the camera and the image processing unit may be adapted for, during the monitoring procedure, acquiring and processing images of the focus area during various runs of the suspension traction member through the focus area at time-shifted intervals.

[0032] In other words, in order to enable detecting failures or deteriorations along the entire length of the STM, the monitoring procedure may be performed not only during a single run of the STM but is extended to a plurality of runs. Therein, during each run, the STM is moved through the focus area of the camera and images are acquired by the camera in certain time intervals. However, the time intervals may be relatively long such that, due to the high velocity with which the STM is moved through the focus area, two images are taken in non-consecutive succession during a single run and do therefore not represent portions of the STM directly adjoining each other but being spaced from each other.

[0033] In order to nevertheless being able to monitor the entire length of the STM or at least major portions thereof without significant "white spaces", i.e. interruptions between neighbouring imaged areas, the monitoring procedure may be extended to a plurality of runs. In each of the runs, images are acquired at specific time intervals and the time intervals are time-shifted at different runs.

[0034] Accordingly, while for example in a first run a first multiplicity of images are taken from a first multiplicity of imaged areas being spaced from each other along the length of the STM, a second multiplicity of images is taken during a second run at locations which, due to the time-shift with respect to the image acquisition in the first run, are locally shifted with respect to the first multiplicity of images. Thus, by performing the monitoring procedure during a plurality of runs, plural first, second and, optionally, third, fourth, etc. multiplicities of images may be acquired in a way such that the sum of all images may cover the surface of the STM along the entire length of the STM.

[0035] By distributing the entire monitoring procedure over a plurality of runs and time-shifting the image acquisition throughout the various runs, requirements concerning an image acquisition rate of the camera as well as a processing power of the image processing unit may be released. For example, a frame rate of the camera may be reduced to e.g. between 25 and 150 Hz.

[0036] According to an embodiment, the camera is arranged at a stationary position within the elevator shaft.

[0037] In other words, the camera may be installed at a fixed position in the elevator shaft such as for example at a shaft wall or at another elevator component fixedly attached to such shaft wall. Installing the camera at a stationary position within the elevator shaft enables simple installation and/or wiring of the camera.

[0038] Furthermore, the camera may be constantly directed to a stationary focus area and may acquire images from such focus area. The location of the focus area may be selected such that upon displacing the STM for displacing the elevator car, portions of the STM move relative to the camera and move through the camera's focus area. Accordingly, during normal operation of the elevator assembly, almost each portion of the STM will sooner or later be moved throughout the focus area of the stationary camera.

[0039] According to an embodiment, the camera is arranged adjacent to the drive engine.

[0040] In other words, the camera may be fixed at a location in close neighbourhood to the drive engine, for example less than 5 m, preferably less than 2 m or less than 1 m, away from the drive engine. Specifically, the camera may be attached directly to the drive engine or may even be included in a housing enclosing the drive engine and/or its traction sheave.

[0041] When being positioned adjacent to the drive engine, the camera may acquire images of the STM upon the STM being displaced by the traction sheave of the drive engine. Accordingly, it has been found that by positioning the camera near the drive engine, all or almost all relevant portions of the STM may be visually monitored using the camera.

[0042] Specifically, according to an embodiment, the elevator assembly further comprises a counterweight which is suspended by the STM. Therein, the suspension traction member extends from the counterweight via a traction sheave of the drive engine to the elevator car. In such configuration, the camera is preferably arranged at the drive engine at a position in close proximity to where the suspension traction member coming from the counterweight reaches the traction sheave.

[0043] In other words, has been found to be beneficial to position the camera at a location close to where the STM approaches the traction sheave of the driving engine on the counterweight-side. For example, the camera may be placed right next to the traction sheave such that it may acquire images of the STM engaging with this traction sheave upon being displaced. For example, the camera may be incorporated into a housing enclosing the traction sheave and/or the drive engine.

[0044] It has been found that, by positioning the camera on a counterweight-side of the drive engine, all or most relevant portions of the STM may be visually monitored using the camera.

[0045] According to an embodiment, the camera is directed to a rear side surface of the suspension traction member. Therein, the rear side surface is opposite to a front side surface coming into contact with the traction surface of the traction sheave, i.e. the rear side surface at a portion of the STM engaging with the traction sheave faces away from the traction sheave.

[0046] In other words, while the camera may, in principle, visually monitor all surfaces of the STM, it may be preferable to use and configure the camera at least for monitoring the rear side surface of the STM. It has been found that this rear side surface is specifically susceptible to visually detectable deteriorations or failures of the STM.

[0047] For example, a polymer overcoating enclosing load carrying cords of the STM is typically thinner at the rear side than at the front side of the STM. Accordingly, damages or deteriorations of such overcoating preferably occur at this rear side.

[0048] Additionally, some typical deteriorations or failures in an STM are preferably visible on the rear side of the STM but do not visibly change the front side of the STM. For example, upon any cord rupture, free ends of the broken cord may penetrate through the enclosing overcoating. Such penetration typically occurs through the overcoating at the rear side of the STM as the free ends of the broken cord are pressed towards this rear side upon the STM being deflected for example at the traction sheave or at a pulley.

[0049] Furthermore, the rear side of the STM is typically flat, i.e. non-textured or non-profiled, whereas the front side of the STM has to provide for suitable traction and guidance for example upon cooperating with the traction sheave of the drive engine and may therefore be textured or profiled. It may be easier to detect any visual changes or deteriorations on the flat rear side surface than on a textured or profiled front side surface.

[0050] According to an embodiment, the elevator assembly may further comprise a second camera. Therein, the second camera may be directed to a front side surface of the suspension traction member. This front side surface is the surface which, when the STM is displaced and is locally engaging with the traction sheave of the drive engine, comes into contact with this traction surface.

[0051] In other words, while it is generally indispensable to monitor the STM's integrity at least by visually monitoring its rear side, it may additionally be beneficial to also provide a camera for monitoring the STM's integrity at its front side surface. Specific deteriorations or damages typically occur at this front side surface.

[0052] For example, upon traction between the STM and the traction sheave of the drive engine, abrasion or wear may occur at the front side surface of the STM due to, for example, dust or dirt being deposited on such front side surface.

[0053] While the front side surface of the STM may be profiled or textured and, therefore, it may be more sophisticated to detect any visual deteriorations or failures at such front side surface, it may nevertheless be beneficial to specifically monitor this front side surface as for example some specific deteriorations or failures exclusively occur at profiled or textured surfaces. For example, interruptions or ruptures of a profile or damages of a texture pattern may occur due to wear or erosion/corrosion and may for example degrade a traction capability or guidance capability upon interaction of the front side surface of the STM with the traction surface of the traction sheave of the drive engine.

[0054] According to an embodiment, the elevator assembly may further comprise a light source which is configured and arranged for illuminating the surface of the suspension traction member where the camera acquires the images, i.e. in the focus area.

[0055] In other words, a lamp or any other illumination means may be provided within the elevator assembly, preferably within the elevator shaft. Using such light source, the camera may be supported in acquiring images of the STM's surface by additionally illuminating the imaged area on the surface of the STM. By increasing the light intensity emitted from such imaged area, an imaging quality of the camera may be enhanced. The light source may be located at or close to the camera. Generally, a spectrum of the light emitted by the light source should be adapted to a sensitivity spectrum of the camera.

[0056] Preferably, according to an embodiment, the light source is configured to emit white light, i.e. light with a broad spectrum extending substantially throughout the entire visible frequency range.

[0057] In principle, any type of light source may be applied for illuminating the imaged area. For example, it could be assumed that it might be beneficial to use light such as infrared light which is invisible for humans for illuminating the imaged area. Thereby, any disturbances for passengers or users of the elevator assembly might be avoided.

[0058] Furthermore, it may be assumed that, for cost reasons and/or complexity reasons, the light source should be as simple as possible and it may therefore be preferable to apply a monochromatic light source such as for example a single-coloured LED (light emitting diode).

[0059] However, it has been found that it may be beneficial to use a light source emitting white light as it enables visually detecting some failures or deteriorations on the STM's surface which would remain invisible in infrared light and/or in monochromatic light. Particularly, it has been found that for example rust, i.e. small red particles, and/or specific types of dust and dirt may only be visually detected when illuminated with white light.

[0060] Furthermore, according to an embodiment, the light source is configured to emit stroboscopic light, i.e. is a stroboscopic light source.

[0061] A stroboscopic light source is configured to emit light in short flashes. For example, light emission may be restricted to less than 100 ms, preferably less than 10 ms or even less than 1 ms. Particularly, a duration of the stroboscopic light flash may be shorter than an image acquisition time of the camera, i.e. the time the camera needs for acquiring a single image. Due to such timely limited illumination, image acquisition by the camera may be improved. Particularly, although the STM is typically displaced with the relatively high velocity with respect to the stationary camera, illuminating the surface of the STM with stroboscopic light flashes may enable acquiring sharper images of the observed surfaces of the STM. Particularly, a periodicity of the stroboscopic light source may be set such that the non-consecutive regions of the suspension traction member to be imaged are suitably illuminated.

[0062] The stroboscopic light source may emit the light flashes periodically. For example, a periodicity may be adapted to characteristics of the camera, specifically to image acquisition times, imaging rates and/or inter-imaging down-times of the camera. For example, flash emission at frequencies of less than 100 Hz, preferably less than 10 Hz or even less than 1 Hz may be applied.

[0063] According to an embodiment, the camera is adapted for acquiring colour images.

[0064] Similar to the optional light used for illuminating the imaged area, it could be assumed at a first view that a monochromatic approach may reduce costs and/or complexity of the camera. Furthermore, an image processing of a monochromatic image may be assumed to be significantly less complex than in case of a coloured image.

[0065] However, as indicated above, some specific deteriorations or failures in an STM are found to be only visually detectable if colours in an acquired image may be suitably resolved. Specifically, deteriorations resulting from corrosion or fretting corrosion may be indicated by the presence of rust or coloured dust which may beneficially be visible in colour images but which may remain invisible in monochromatic images.

[0066] According to an embodiment, the image processing unit comprises a digital signal processor.

[0067] A digital signal processor (DSP) may continuously process digital signals such as video signals transmitted by the camera using digital signal processing. Analogue signals may be processed using AD (analogue - digital) converters and DA converters, respectively. DSPs may not only be applied for replacing complex analogue filter techniques but may also fulfil further tasks which may hardly be realised using conventional analogue techniques, such as, inter-alia, frequency filtering at low phase errors, dynamic compression and noise reduction, echo suppression, data compression, very fast digital image processing, etc. Furthermore, today, DSPs may be provided at low costs and high reliability.

[0068] According to an embodiment, the image processing unit is adapted for comparing the acquired images with reference images and detecting the deterioration in the STM based upon such comparison.

[0069] In other words, the image processing unit may determine whether or not visually detectable deteriorations or changes are present at the observed surface of the STM based on a comparison of actually acquired images with reference images. Accordingly, a currently acquired image of the surface of the STM may be compared with a reference image and, upon detecting significant differences between the acquired image and the reference image, the image processing unit may determine whether such differences relate to a critical deterioration or failure of the STM, such as e.g. a crack or rupture, or whether the differences only relate to minor changes, such as e.g. a local imprint or a noncritical deposit of dust.

[0070] The reference images may be for example images previously taken from the STM in a non-deteriorated state, i.e. for example directly after fabrication of the STM. Alternatively, the reference images may be previously acquired images of other portions of the surface of the STM. For example, a multiplicity of reference images may represent an average state of the STM and significant deviations from such average state in locally imaged areas may be taken as indicating local deteriorations or failures of the STM.

[0071] The reference images may be stored for example in a machine readable form, i.e. for example in electronic or magnetic memory provided in the image processing unit.

[0072] Image processing based on comparing acquired images with reference images may be simple and fast. Furthermore, typically no high processing power has to be provided as for example no complex algorithms are to be performed. Accordingly, a relatively simple and cheap CPU may be applied in the image processing unit.

[0073] According to an embodiment, the elevator assembly may be adapted to, during the monitoring procedure, displace the suspension traction member at a reduced velocity compared to a normal operation velocity.

[0074] Due to such reduced displacement velocity, the STM is moved through the focus area of the camera with a reduced speed. Accordingly, the camera may acquire images of succeeding neighbouring areas of the surface of the STM with a relatively low frame rate. For example, the displacement velocity may be reduced during the monitoring procedure to 50% or less, preferably to 30% or less or even 10% or less, compared to a displacement velocity during normal operation of the elevator assembly. For example, the monitoring procedure may be performed during a specific monitoring run in which the STM is moved through the camera's focus area at a low speed of for example less than 2m/s, preferably less than 1m/s or even less than 0,3m/s. Such slow monitoring run may be performed for example in times in which the elevator assembly is typically not used such as for example during early morning times.

[0075] According to an embodiment, position information, in particular absolute position information is provided and associated with an acquired image to define a position, in particular an absolute position, of an acquired image on the surface of the suspension traction member.

[0076] In other words, (absolute) position information is acquired and preferably stored associated to an acquired image so as to allow retaining information of where along the length of the suspension traction member a particular image was acquired. By analysing (absolute) position information, it may subsequently be determined whether the complete or substantially complete suspension traction member has been imaged during a particular time period. The (absolute) position information may be stored together with the acquired image information, e.g. as a location stamp embedded within the image information or in a separate database linked to a single image or a series of images. Further a certain timestamp may be associated with the image information comparably with the above described position/location information to allow an analysis of the suspension traction member over time.

[0077] It shall be noted that possible features and advantages of embodiments of the invention are described herein partly with respect to an elevator assembly and partly with respect to a specific way of operating such elevator assembly. One skilled in the art will recognize that the features may be suitably transferred from one embodiment to another and features may be modified, adapted, combined and/or replaced, etc. in order to come to further embodiments of the invention.

[0078] In the following, advantageous embodiments of the invention will be described with reference to the enclosed drawings. However, neither the drawings nor the description shall be interpreted as limiting the invention.

Fig. 1 shows an elevator assembly according to an embodiment of the present invention.

Fig. 2 shows details of a camera system for the elevator assembly of Fig. 1.

Fig. 3 visualizes portions of an STM to be monitored in an elevator assembly according to an embodiment of the present invention.

Fig. 4 shows a detailed exemplary implementation of a camera system for an elevator assembly according to an embodiment of the present invention.

[0079] The figures are only schematic and not to scale. Same reference signs refer to same or similar features.

[0080] Fig. 1 shows an embodiment of an elevator assembly 1. The elevator assembly 1 comprises an elevator car 3 which may be displaced within an elevator shaft 5. The elevator car 3 is suspended by a suspension traction member 7. The STM 7 typically comprises several belts 43 or ropes. For example, each belt 43 may comprise a plurality of load carrying cords embedded in a polymer matrix material forming an overcoat. In the configuration shown in Fig. 1, opposite ends of the STM 7 are attached to a fixation point 31, respectively, being provided for example at a ceiling or at walls of the elevator shaft 5. Additionally to the elevator car 3, the STM 7 also suspends a counterweight 27 via a pulley 29 attached thereto. Between the elevator car 3 and the counterweight 27, the STM 7 is wound around a traction sheave 11 of a drive engine 9 such that the drive engine 9 may displace the STM 7, thereby suitably displacing the elevator car 3 and the counterweight 27. Operation of the drive engine 9 is controlled by an elevator control 23.

[0081] A surface of the STM 7 coming into contact with a traction surface of the traction sheave 11 will be referred to herein as front side surface 6 of the STM 7. Such front side surface 6 may be profiled or textured. For example, elongate grooves may extend along the length of the front side surface 6 and may support guidance of the STM 7 on the traction sheave 11. An opposite side of the STM 7 is referred to herein as rear side surface 8 of the STM 7. Such rear side surface 8 is typically non-profiled and non-textured, i.e. may be for example flat.

[0082] An integrity of the STM 7 and its belts 43 may be continuously or repeatedly monitored using a camera system 13. Possible details of such camera system 13 are shown in Fig. 2. The camera system 13 comprises a camera 15 and an image processing unit 17. The camera 15 comprises an optics 14 and a light-sensitive sensor 16. The optics 14 may project a focus area 18 onto a light receiving surface of the light-sensitive sensor 16 such that the light-sensitive sensor 16 may acquire an image of the focus area 18.

[0083] In the elevator assembly 1, the STM 7 or at least one of its belts 43 may be arranged in the focus area 18 of the camera 15, with its rear side surface 8 preferably being directed towards the camera 15. Upon displacing the STM 7 for moving the elevator car 3, the STM 7 may be displaced through the focus area 18 in motion directions indicated with the arrow 20.

[0084] Images acquired by the camera 15 are transmitted to the image processing unit 17. This image processing unit 17 may comprise for example a digital signal processor (DSP) and may process and analyse data of the acquired images of the observed rear side surface 8 of the STM 7 in order to thereby detect any abnormalities.

[0085] Such abnormality may be for example a cord or wire break coming out of the overcoat, a longitudinal or transverse crack or abrasion, a piercing of the overcoat, corrosion or fretting corrosion and/or a damage of an edge of the belt 43. All such abnormalities may result in a change of a visual appearance of the rear side surface 8 of the STM and may therefore be observed by the camera 15.

[0086] For example, the image processing unit 17 may compare actually acquired images of a portion of the rear side surface 8 of the STM 7 with previously acquired reference images. Such reference images may be acquired at a point in time where the STM 7 definitely does not yet comprise any deteriorations. Alternatively, the reference images may be acquired from other definitely non-deteriorated portions of the STM 7. Upon such comparison, the image processing unit 17 may detect abnormalities in the visual appearance of the STM's 7 surface.

[0087] Accordingly, by processing and analysing images acquired by the camera 15 during a monitoring procedure, various kinds of visual deteriorations of the STM 7 may be detected. Upon detection of such visual deterioration, the image processing unit 17 may issue a signal. Such signal may then for example be transmitted to a contactor 19 being part of a safety chain 21 of the elevator assembly 1 such that, upon interruption of the contactor 19, the safety chain 21 is opened and, in response thereto, the elevator control 23 therefore may stop or modify the operation of the elevator assembly 1. Alternatively to such configuration with a contactor 19 being manipulated by the image processing unit 17, the signal issued by the image processing unit 17 could for example be transmitted to the elevator control 23 via a data bus system. Furthermore, the signal may also be transmitted to a remote control or monitoring unit which controls and/or supervises correct operation of the elevator assembly.

[0088] In order to obtain high-quality images of the STM 7, the camera system 13 may further comprise a light source 25 for illuminating the focus area 18. Such light source 25 may be included in a common housing of the camera system 13 or may be provided as a separate device. Preferably, the light source 25 emits white light or at least light with a broad spectrum. The camera 15 may be adapted for acquiring colour images. Accordingly, some deteriorations such as local occurrence of rust or fretting corrosion may be well visible in acquired high-contrast colour images and may therefore be reliably detected by the image processing unit 17.

[0089] Furthermore, the light source 25 may be adapted for emitting stroboscopic light flashes. Operation of the light source 25 may be controlled for example via the image processing unit 17. Accordingly, an image acquisition by the camera 15 and an emission of light flashes by the light source 25 may be synchronised.

[0090] In order to reduce the costs of the image processing unit 17 preferably including a DSP, an image frame rate could be reduced to between 25 and 150 Hz. In other words, images may be taken at relatively long time intervals of more than e.g. 5 ms or even up to 40 ms. While such relatively slow repetitive image acquisition may enable using electronic components of relatively low complexity and costs, in some cases, resulting snapshots of the surface of the STM 7 may be non-adjacent and the surface of the entire STM 7 could not be recorded entirely in a single trip or run, i.e. upon displacing the elevator car 3 from one extreme petition to the opposite extreme position.

[0091] In order to avoid that some spaces between non-consecutive, i.e. non-adjacent, snapshots of the surface of the STM 7 remain non-monitored, the monitoring procedure may be extended over more than one trip, for example over two, three or even more trips and, in each of these trips. Images may be acquired (i.e. snapshots may be taken) in each of the trips at a variable time delay, i.e. at time-shifted intervals. The variable time delay between the image series could then be implemented to achieve a full coverage of the STM's 7 surface in several trips or runs.

[0092] Alternatively, in order to monitor the entire STM 7 along its full length in only a single run, a specific monitoring run may be performed for the monitoring procedure, during which monitoring run the STM 7 is displaced with a significantly reduced velocity compared to a normal operation velocity.

[0093] As shown in Fig. 1, the camera system 13 may be arranged at a stationary position within the elevator shaft 5. Preferably, it is arranged close to the drive engine 9. Such positioning could be used both in the exemplary 2:1 installation shown in Fig. 1 and 3 as well as in other possible installations such as for example a 1:1 installation (not shown). An actual scanning and monitoring of the STM 7 may then be achieved when the elevator is moving and the STM 7 is running under the camera system 13.

[0094] Preferably, the camera system 13 may be installed at or close to the drive engine 9 at a location in close proximity to where the STM 7 coming from the counterweight 27 reaches the traction sheave 11. Such configuration is shown in Fig. 3. Therein, Fig. 3(a) shows an extreme situation in which the elevator car 3 is driven to its lowermost position and the counterweight 27 is driven to its uppermost position, whereas Fig. 3(b) shows the other extreme situation in which the elevator car 3 is driven to its uppermost position and the counterweight 27 is driven to its lowermost position. In both Fig. 3(a) and (b), those portions which may be monitored with the camera system 13 are indicated with a thicker line for the STM 7 (of course the actual STM has a uniform thickness). It may be seen that in such configuration in which the camera system 13 is arranged close to the drive engine 9, the STM 7 may be monitored along major portions of its entire length and only some minor regions close to the fixation point 31 may not be monitored with the camera system 13.

[0095] It may be noted that in case the camera system 13 is not fixedly installed in the elevator shaft 5 close to the drive engine 9 but for example is fixed to the elevator car 3, a portion of the STM 7 which may be monitored by the camera system 13 would be significantly shorter.

[0096] Finally, a detailed exemplary implementation of a camera system 13 for an elevator assembly 1 will be described with reference to Fig. 4. Components of the camera system 13 are comprised within a common housing 41. This housing 41 is arranged at or closely neighbouring to the drive engine 9 and may be attached for example to a motor mount 10. Several belts 43 of an STM 7 being driven by the drive engine 9 are guided through the housing 41. At opposite sides of these belts 43, the camera system 13 comprises a master sensor board 33 and a slave sensor board 35 being electrically connected to the master sensor board 33. At locations close to one or more of the belts 43, a camera 15 is arranged at each of opposite sides of the belts 43. This means that at least one camera 15 is provided at the master sensor board 33 and at least one camera 15 is provided at the slave sensor board 35, respectively, such that both of opposite front and rear surfaces 6, 8 of the belts 43 may be observed by the cameras 15. In the example shown, one camera 15 is associated to two of the belts 43 such that an optics and a light-sensitive sensor (not specifically visualised in figure 4) are adapted for acquiring images of a front side surface 6 or rear side surface 8 of both belts 43, respectively. In order to illuminate these front and rear side surfaces 6, 8, light sources is 25 comprising for example several light emitting diodes (LEDs) 37 are provided adjacent to the respective camera 15 at both the master sensor board 33 and the slave sensor board 35. The LEDs 37 preferably emit white light and the cameras 15 acquire colour images. Image data acquired by the cameras 15 is transmitted to a central processing unit (CPU) 39 forming or being part of the image processing unit 17.

[0097] Overall, using the camera (15) and the image processing unit (17) as described herein, deteriorations of the suspension traction member (7) resulting in changes in its visual appearance may be detected and measures e.g. for increasing safety of the elevator assembly (1) may be initiated correspondingly.

[0098] Finally, it should be noted that the term "comprising" does not exclude other elements or steps and the "a" or "an" does not exclude a plurality. Also elements described in association with different embodiments may be combined. It should also be noted that reference signs in the claims should not be construed as limiting the scope of the claims.

List of reference signs

[0099]

1 elevator assembly
3 elevator car

5 elevator shaft
6 front side surface of STM
7 suspension traction member
8 rear side surface of STM
9 drive engine
10 motor mount
11 traction sheave
13 camera system
14 optics
15 camera
16 light-sensitive sensor
17 image processing unit
18 focus area
19 contactor
20 motion direction
21 safety chain
23 elevator control
25 light source
27 counterweight
29 pulleys
31 fixation points
33 master sensor board
35 slave sensor board
37 LEDs
39 CPU
41 housing
43 belts

Claims

1. Elevator assembly (1) comprising:

an elevator car (3) being displaceable within an elevator shaft (5);
a suspension traction member (7) suspending the elevator car (3);
a drive engine (9) driving a traction sheave (11) for displacing the suspension traction member (7) running along a traction surface of the traction sheave (11);
a camera (15); and
an image processing unit (17);
wherein the camera (15) is directed towards the suspension traction member (7) for acquiring images of a surface (6, 8) of the suspension traction member (7) during a monitoring procedure for monitoring a deterioration state of the suspension traction member (7);
wherein the image processing unit (17) is adapted for processing and analysing the images acquired by the camera (15) during the monitoring procedure for detecting visual deteriorations of the suspension traction member (7) and for generating a signal upon detection of such visual deteriorations,
wherein the camera (15) and the image processing unit (17) are adapted for, during the monitoring procedure, acquiring and processing images of a focus area (18) in predetermined time intervals such as to acquire images of non-consecutive regions of the surface (6, 8) of the suspension traction member (7) while the suspension traction member (17) moves through the focus area (18).

2. Elevator assembly of claim 1, wherein the camera (15) and the image processing unit (17) are adapted for, during the monitoring procedure, acquiring and processing images of the focus area (18) during various runs of the suspension traction member (7) through the focus area (18) at time-shifted intervals.

3. Elevator assembly of one of the preceding claims, wherein the camera (15) is arranged at a stationary position within the elevator shaft (5).

4. Elevator assembly of one of the preceding claims, wherein the camera (15) is arranged adjacent to the drive engine (9).

5. Elevator assembly of one of the preceding claims, further comprising a counterweight (27) which is suspended by the suspension traction member (7), wherein the suspension traction member (7) extends from the counterweight (27) via a traction sheave (11) of the drive engine (9) to the elevator car (3), wherein the camera (15) is arranged at the drive engine (9) at a position in close proximity to where the suspension traction member (7) coming from the counterweight (27) reaches the traction sheave (11).

6. Elevator assembly of one of the preceding claims, wherein the camera (15) is directed to a rear side surface (8) of the suspension traction member (7), the rear side surface (8) being opposite to a front side surface (6) coming into contact with the traction surface of the traction sheave (11).

7. Elevator assembly of one of the preceding claims, further comprising a second camera (15), wherein the second camera (15) is directed to a front side surface (6) of the suspension traction member (7) coming into contact with the traction surface of the traction sheave (11).

8. Elevator assembly of one of the preceding claims, further comprising a light source (25) which is configured and arranged for illuminating the surface (6, 8) of the suspension traction member (7) where the camera (15) acquires the images.

9. Elevator assembly of claim 8, wherein the light source (25) is configured to emit white light.

10. Elevator assembly of one of claims 8 and 9, wherein the light source (25) is configured to emit stroboscopic light.

11. Elevator assembly of one of the preceding claims, wherein the camera (15) is adapted for acquiring colour images.

12. Elevator assembly of one of the preceding claims, wherein the image processing unit (17) comprises a digital signal processor.

13. Elevator assembly of one of the preceding claims, wherein the image processing unit (17) is adapted for comparing the acquired images with reference images and detecting the deterioration based upon such comparison.

14. Elevator assembly of one of the preceding claims, wherein the elevator assembly (1) is adapted to, during the monitoring procedure, displace the suspension traction member (7) at a reduced velocity compared to a normal operation velocity.

15. Elevator assembly of one of the preceding claims, wherein position information, in particular absolute position information is provided and associated with an acquired image to define a position, in particular an absolute position, of an acquired image on the surface (6, 8) of the suspension traction member (7).

Fig. 1

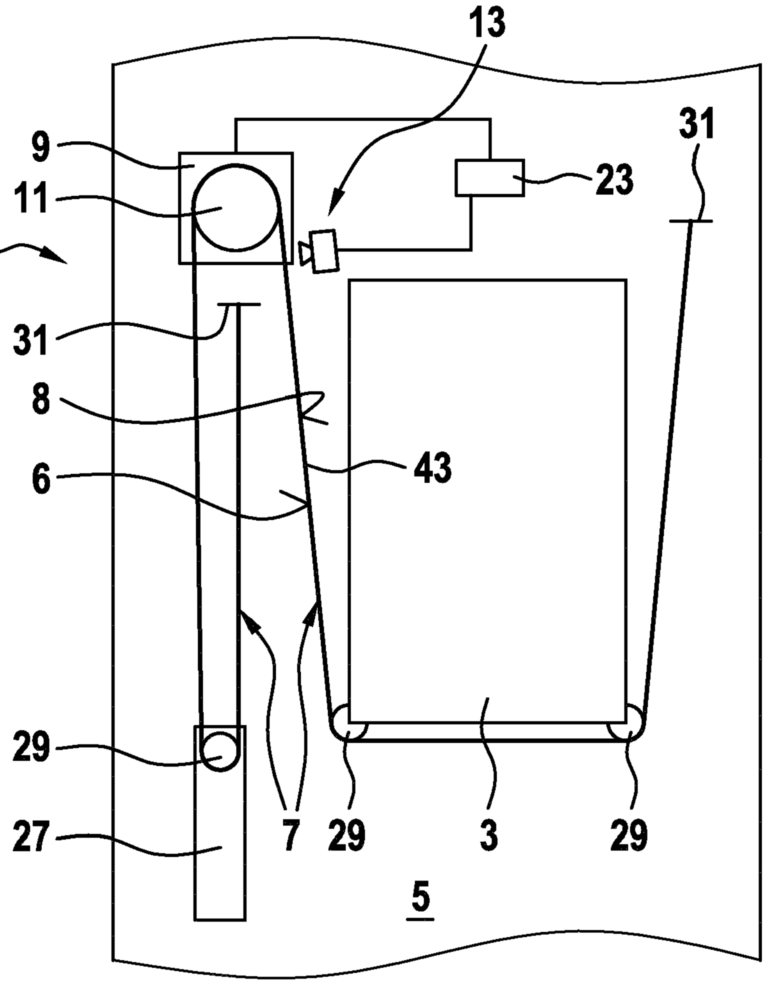
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Fig. 2

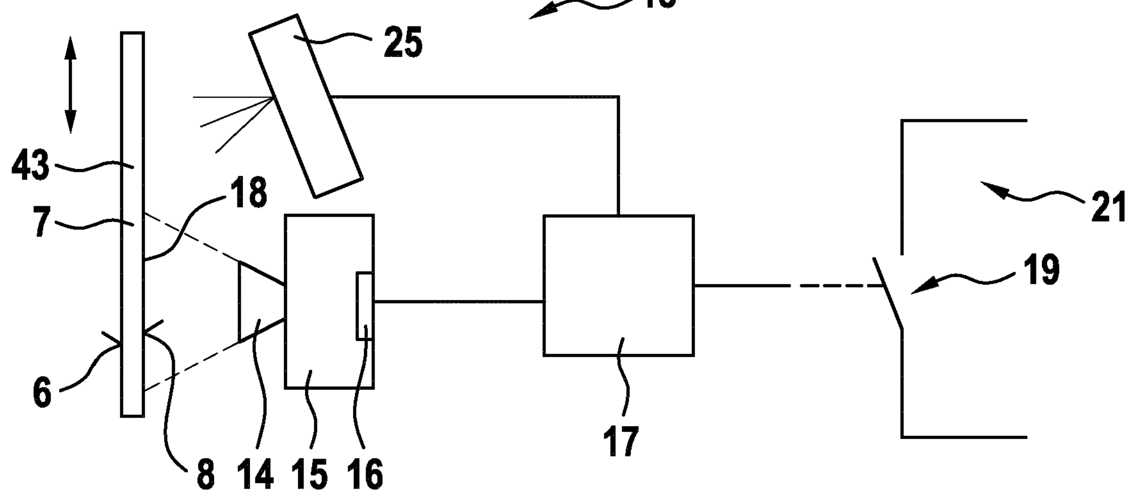
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Fig. 3(a)

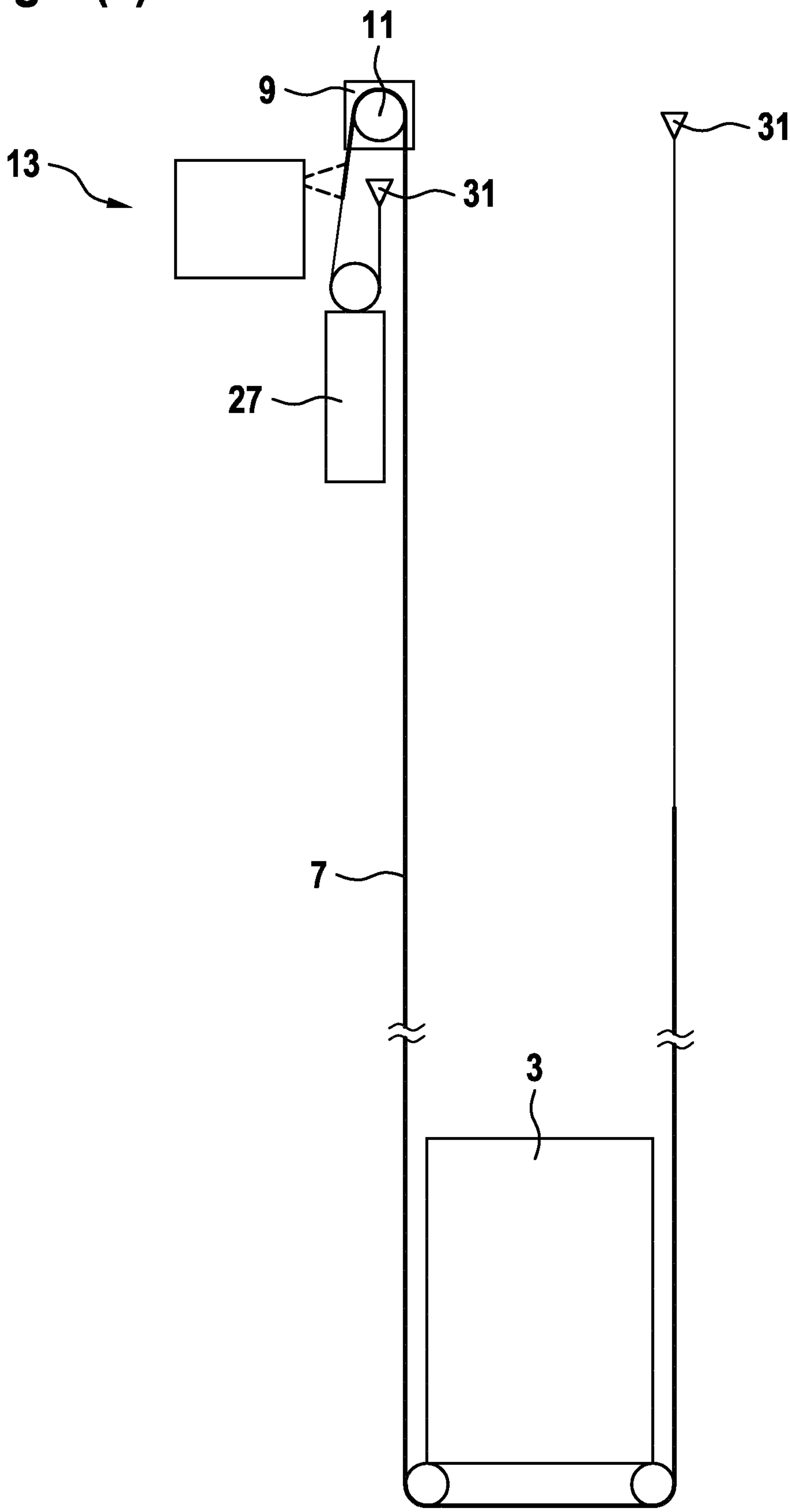


Fig. 3(b)

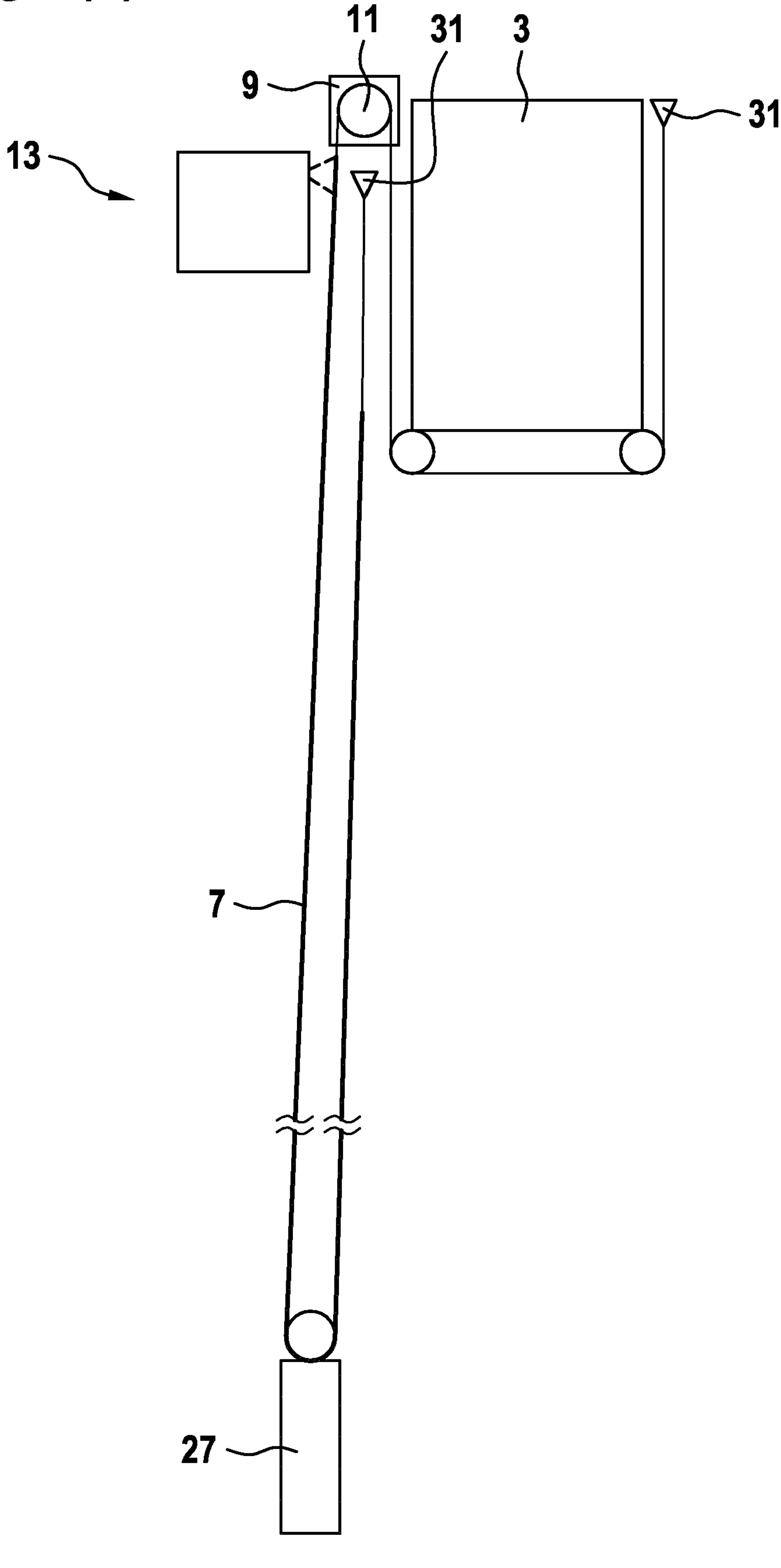
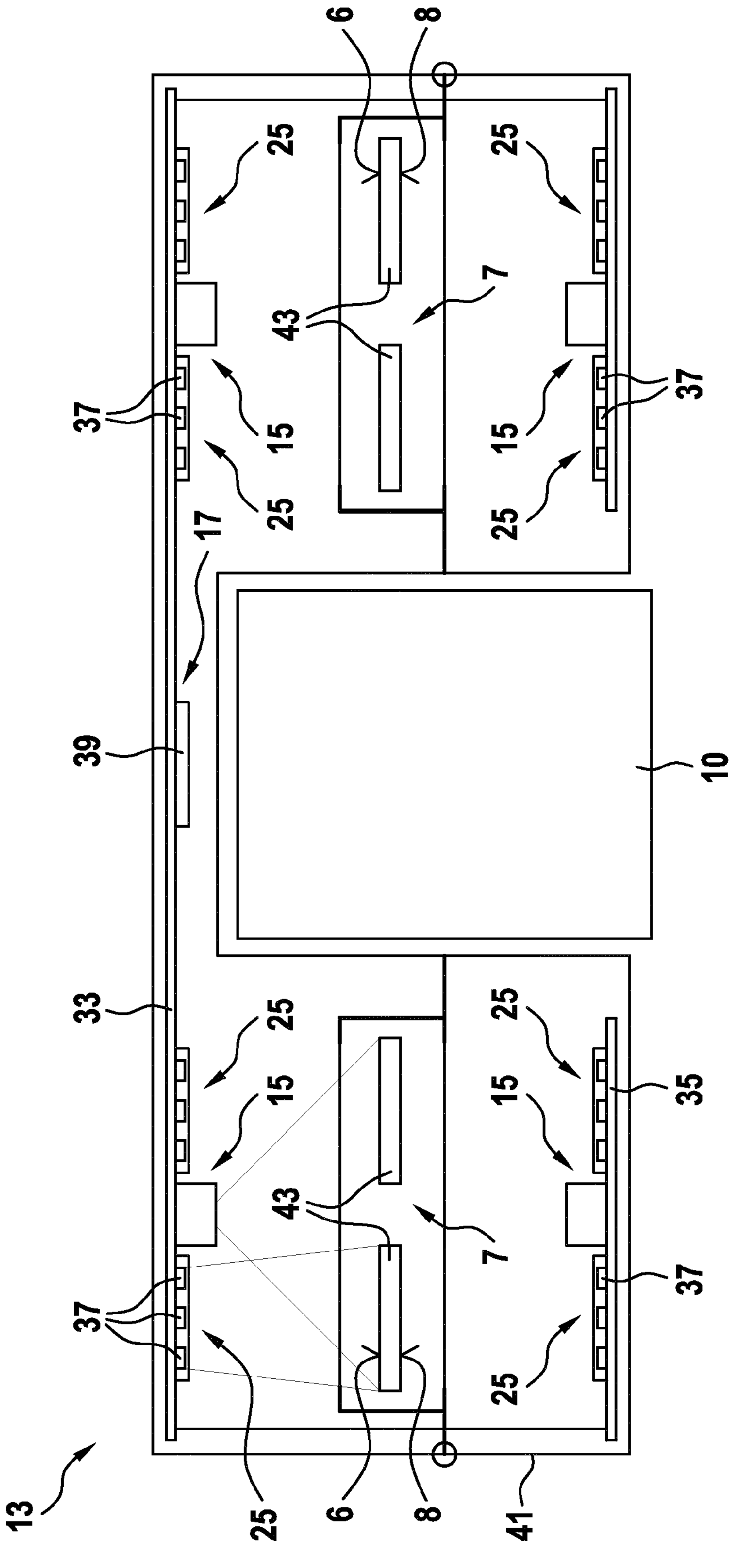


Fig. 4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EUROPEAN SEARCH REPORT

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EP 16 20 0551

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TECHNICAL FIELDS SEARCHED (IPC)
B66B

The present search report has been drawn up for all claims

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Place of search	Date of completion of the search	Examiner
The Hague	16 June 2017	Bleys, Philip

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