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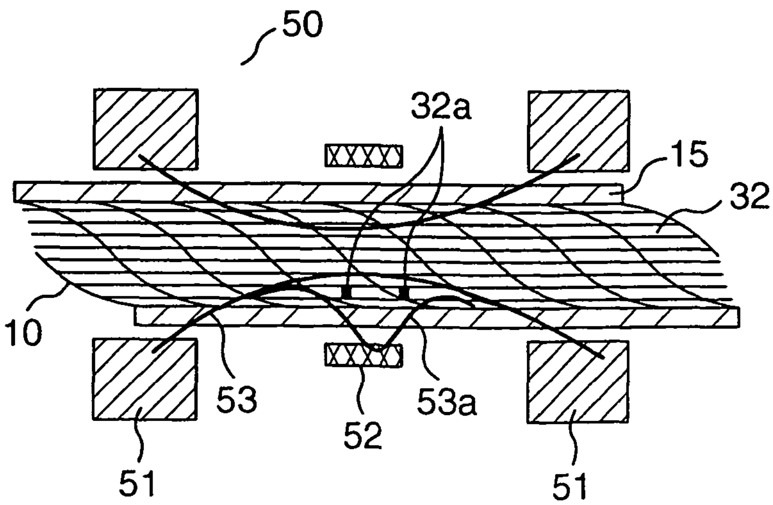
Remarks:
This application was filed on 04 - 04 - 2007 as a divisional application to the application mentioned under INID code 62.

(54) **Method and apparatus for detecting a damage of a rope**

(57) In a rope including a bundle of wires (21, 31, 32), a method for detecting a damage comprises the steps of generating a magnetic field in the bundle of wires, and measuring a leakage of a magnetic flux from the bundle of wires so that the damage of the rope is detected corresponding to a degree of the leakage of the magnetic flux.

FIG. 2



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Description

Background of the Invention

[0001] The present invention relates to a rope usable in an apparatus for moving an object, for example, an elevator, and a method for measuring a damage of the rope. In a prior art rope as disclosed by JP-A-2001-262482, outer peripheries of wires are respectively coated with a synthetic resin, each of bundles of the wires is twisted, the bundles of the wires are twisted to form the rope, and an outer periphery of the rope is coated with the synthetic resin.

[0002] In a prior art rope as disclosed by JP-A-8-261972, aramid fiber and carbon fiber are twisted to form the rope, carbon fiber is breakable prior to a breakage of the aramid fiber, and a breakage of the carbon fiber is detected from a voltage increase through the carbon fiber.

[0003] In a prior art rope as disclosed by JP-A-2001-302135, the rope includes an optical fiber, and a deterioration of the rope is detected from a decrease of optical conductivity of the optical fiber.

Brief Summary of the Invention

[0004] An object of the present invention is to provide a rope in which a damage thereof is securely and easily detectable, and a method for detecting the damage of the rope securely and easily.

[0005] In a rope comprising a bundle of wires each of which is adapted to bear a tensile load to be borne by the rope, since predetermined one of the wires is configured to be at least partially breakable by applying tension and flexure to the rope, before an at least partial breakage of a rest of the wires other than the predetermined one of the wires by applying the tension and flexure to the rope so that the at least partial breakage occurs securely on the predetermined one of the wires before the at least partial breakage of the rest of the wires, the damage of the rope is measurable by monitoring only the predetermined one of the wires so that the damage thereof is securely and easily detectable.

[0006] If the predetermined one of the wires is capable of having at least one of a maximum (highest) stress generated in the predetermined one of the wires by at least one of the tension and flexure greater than maximum (highest) stresses generated in the wires of the rest by the at least one of the tension and flexure, and a (fatigue) strength (per unit cross sectional area) of the predetermined one of the wires against stress generated in the predetermined one of the wires by the at least one of the tension and flexure lower than (fatigue) strength (per unit cross sectional areas) of the wires of the rest against stresses generated in the wires of the rest by the at least one of the tension and flexure, in such a manner that the predetermined one of the wires is capable of having the maximum stress generated in the predetermined one of the wires by at least one of the tension and flexure greater than the (fatigue) strength (per unit cross sectional area) of the predetermined one of the wires against stress generated in the predetermined one of the wires by the at least one of the tension and flexure, for example, the predetermined one of the wires is capable of having the maximum stress generated in the predetermined one of the wires by the at least one of the tension and flexure greater than the maximum stresses generated in the wires of the rest by the at least one of the tension and flexure when a (fatigue) strength (per unit cross sectional area) of the predetermined one of the wires against stress generated in the predetermined one of the wires by the at least one of the tension and flexure is not more than (fatigue) strengths (per unit cross sectional areas) of the wires of the rest against stresses generated in the wires of the rest by the at least one of the tension and flexure, and/or the predetermined one of the wires has the (fatigue) strength (per unit cross sectional area) against stress generated in the predetermined one of the wires by at least one of the tension and flexure lower than the (fatigue) strengths (per unit cross sectional areas) against stresses generated in the wires of the rest by the at least one of the tension and flexure, when a maximum stress generated in the predetermined one of the wires by the at least one of the tension and flexure is not less than maximum stresses generated in the wires of the rest by the at least one of the tension and flexure, the at least partial breakage occurs securely on the predetermined one of the wires before the at least partial breakage of the rest of the wires.

[0007] If at a longitudinal position of the rope, a cross sectional area of the predetermined one of the wires is greater than cross sectional areas of the rest of the wires, the maximum stress generated in the predetermined one of the wires by the at least one of the tension and flexure is greater than maximum stresses generated in the wires of the rest by the at least one of the tension and flexure, and/or the (fatigue) strength (per unit cross sectional area) against stress generated in the predetermined one of the wires by at least one of the tension and flexure is decreased by size effect in (fatigue) strength in comparison with the (fatigue) strengths (per unit cross sectional areas) against stresses generated in the wires of the rest by the at least one of the tension and flexure, so that the at least partial breakage occurs securely on the predetermined one of the wires before the at least partial breakage of the rest of the wires. It is preferable that cross sectional areas of the predetermined one of the wires and the wires of the rest are constant respectively in a longitudinally direction of the bundle of wires.

[0008] If at least a part of the predetermined one of the wires is arranged at a relatively radially outer side with respect to the rest of the wires in the rope, or at least a longitudinal part of the predetermined one of the wires is arranged at an outer periphery of the bundle of wires, the at least partial breakage of the predetermined one of the wires on the outer periphery of the bundle of wires is securely generated by the relatively greater maximum (highest) stress of the predetermined one of the wires in comparison with the rest of the wires because the stress in the rope increases in accordance with a radial distance of a position on which the stress is generated and a radial center (radially zero position) of the rope, or if at a longitudinal position of the rope, the predetermined one of the wires is arranged at the outer periphery of the bundle of wires while at the longitudinal position of the rope, the cross sectional area of the predetermined one of the wires is greater than the cross sectional areas of the rest of the wires, the at least partial breakage of the predetermined one of the wires on the outer periphery of the bundle of wires is securely generated by the relatively greater maximum (highest) stress of the predetermined one of the wires in comparison with the rest of the wires and the relatively smaller strength caused by size effect in strength in comparison with the rest of the wires to be easily measurable and/or visible from the outside of the bundle of wires.

[0009] It is preferable for securely detecting the at least partial breakage of the predetermined one of the wires that the whole length of the predetermined one of the wires is arranged at an outer periphery (radially outermost position) of the bundle of wires.

[0010] It is preferable for securely making the maximum (highest) stress of the predetermined one of the wires more than the maximum (highest) stresses the rest of the wires that a modulus of longitudinal elasticity of the predetermined one of the wires is more than moduluses of longitudinal elasticities of the wires of the rest in the rope.

[0011] The predetermined one of the wires and the wires of the rest may be metallic, and the predetermined one of the wires may be magnetically permeable so that the breakage of the predetermined one of the wires can be magnetically. The predetermined one of the wires and the wires of the rest may be electrically conductive. The predetermined one of the wires may be electrically connected to the wires of the rest in such a manner that an electric potential difference between longitudinally opposite ends of the predetermined one of the wires in a longitudinal length of the rope is equal to electric potential differences between longitudinally opposite ends of the wires of the rest in the longitudinal length of the rope, so that an electrochemical corrosion on the wires is restrained. A main component of the predetermined one of the wires may be equal to a main component of the rest of the wires. The bundle of wires may be twisted. The bundle of wires may include a first twisted bundle of the wires and a second twisted bundle of the wires, and the second twisted bundle extends helically around the first twisted bundle of the wires to surround the first twisted bundle of the wires. It is preferable for positioning the predetermined one of the wires to securely and easily detect the at least partial breakage thereof that the predetermined one of the wires is included by the second twisted bundle of the wires. The rope may further comprises a synthetic resin cover surrounding the second twisted bundle.

[0012] In the bundle of wires including the wires of the rest and predetermined at least two of the wires configured to be at least partially breakable by applying at least one of the tension and flexure to the rope before the at least partial breakage of the rest of the wires, if the predetermined at least two of the wires contact at least partially each other in a direction perpendicular to longitudinal directions of the wires while at least one of the wires of the rest is prevented from interrupting at least partially the at least partial contact between the predetermined at least two of the wires, a transition of the at least partial breakage between the predetermined at least two of the wires is maintained to securely and easily detect the at least partial breakage of the predetermined at least two of the wires.

[0013] Since a method for detecting a damage of the above rope comprises the steps of : generating a magnetic field in the bundle of wires, and measuring a leakage of a magnetic flux from the bundle of wires so that a damage of rope corresponding to a degree of the leakage of the magnetic flux is detected, the damage of rope can be detected in non-contact with respect to the rope even when the rope is running. It is preferable in this case that the magnetic flux extends longitudinally in the bundle of wires.

[0014] Since an apparatus for detecting a damage of the above rope comprises, a pair of magnetic cores magnetizable to generate a magnetic field in the bundle of wires, and a magnetic sensor for measuring a leakage of a magnetic flux from the bundle of wires so that a damage of rope corresponding to a degree of the leakage of the magnetic flux is detected, the damage of rope can be detected in non-contact between the rope and each of the pair of magnetic core and the magnetic sensor even when the rope is running. It is preferable in this case that the magnetic cores are spaced apart from each other in a longitudinal direction of the bundle of wires to generate the magnetic flux extending longitudinally,in the bundle of wires, and the magnetic sensor is measurable the leakage of the magnetic flux at a position between the magnetic cores in the longitudinal direction.

[0015] Other objects, features and advantages of the invention will become apparent from the following description of the embodiments of the invention taken in conjunction with the accompanying drawings.

Brief Description of the Several Views of the Drawings

[0016]

Fig. 1 is a cross sectional view of a rope of the invention taken along an imaginary plane transverse a longitudinal direction of the rope.

Fig. 2 is a cross sectional view of the rope and a damage detecting device of the invention taken along an imaginary plane parallel to the longitudinal direction of the rope.

Fig. 3 is a diagram showing a relationship between a number of bending times and each of a number of broken metallic wires and a tensile strength of the rope.

Fig. 4 is a flow chart showing a process for detecting a damage of the rope.

Fig. 5 is a cross sectional view of another rope of the invention taken along the imaginary plane transverse a longitudinal direction of the rope.

Fig. 6 is a cross sectional view of another rope of the invention taken along the imaginary plane transverse a longitudinal direction of the rope.

Fig. 7 is a schematic oblique projection view of an elevator in which the rope of the invention is usable.

Detailed Description of the Invention

[0017] In Fig. 7, pulleys 5a and 5b for receiving a rope 10 are mounted on a lower part of a car 1 for carrying a passenger(s) or load, and a pulley 5e for receiving the rope is arranged above a counterweight 2 counterpoising the car 1 when about a half of a safe working load is borne by the car 1. Pulleys 5c and 5d for receiving the rope 10 are arranged at a top of a hoistway 7, and a driving device 3 including a sheave 3a is arranged at a lower part of the hoistway 7. The rope 10 of the invention extends from a rope holder 6a arranged at the top of the hoistway 7, onto the pulleys 5a and 5b on the lower part of the car 1 and the pulley 5c on the top of the hoistway 7 so that the rope 10 is wrapped around the sheave 3a of the driving device 3. The rope 10 further extends on the pulley 5d at the top of the hoistway 7 and the pulley 5e of the counterweight 2, and terminates at a rope holder 6b at the top of the hoistway 7.

[0018] The rope 10 is bendy, and has a great friction-coefficient between the sheave 3a and a coating of the rope, so that the rope 10 has a longer operating life and can transmit securely a driving force even when a diameter of the sheave is small. For, example, the diameter of the sheave may be from one third to a half in comparison with the prior art sheave. Therefore, a driving torque of the driving device may be from one third to a half in comparison with the prior art driving device so that the driving device can be significantly downsized. Further, diameters of the pulleys at the lower part of the car 1, above the counterweight 2 and the top of the hoistway 7 are decreased similarly so that an overhead (a distance between the highest floor and a ceiling of the hoistway) and a pit depth (a distance between the lowest floor and a pit of the hoistway) can be decreased.

[0019] In Fig. 1, a synthetic resin coating 15 is formed on an outside of a first structure 12 arranged at a central portion of the rope 10 and second structures 13 arranged around the first structure 12.

[0020] The first structure 12 is formed by, for example, twisting strands 22 around a core 23 to form an inner structure 24, each of which strands is formed by twisting metallic wires 21 substantially parallel to each other, and forming an organic material coating 25 on an outer periphery of the inner structure 24. The core 23 may be formed of single organic material (resin), a rope of organic material (resin) or a strand which is formed by twisting metallic wires. For obtaining a longer operating life, the core 23 formed of resin is preferable. Clearances are formed between the strands 22 adjacent to each other to be filled with the coating 25.

[0021] Each of the second structure 13 is formed by twisting metallic wires 31 and 32 substantially parallel to each other to form an outer structure 33, and forming an organic material coating 34 on an outer periphery of the outer structure 33. The metallic wires 32 are arranged at an outer periphery of the outer structure 33. In this case, diameters of the metallic wires 32 are greater than those of the metallic wires 21 and 31 or a strength of each of the metallic wires 32 is smaller than that of the metallic wires 21 and 31.

[0022] A pressing force is generated between the first structure 12 and each of the second structures 13 twisted around the first structure 12 by a tension applied to the rope 10, and a radial pressing force is also generated therebetween by pressing the rope against the pulleys and sheave. Flexures of the rope are generated at every passes of the rope on the pulleys and sheave. In this actual operating condition, compressive pressures are generated between the first structure 12 and each of the second structures 13 and between the metallic wires 21, 31, 32, and a flexural stress in each of the metallic wires and mutual slip between the metallic wires are generated. Therefore, the metallic wires are at least partially broken by stress variation and slip under the compressive pressures causing a fretting. A stress generated in the metallic wire by the flexures of the rope increases in accordance with an increase of radial distance of a position of the metallic wire from a radial center of the rope and an increase of diameter of the metallic wire. Further, a slip on the metallic wire increases in accordance with the increase of radial distance of the position of the metallic wire from the radial center of the rope. That is, the radially outermost metallic wire bears the most severe condition.

[0023] In the rope, a coating 25 is inserted between the strands 22 of the first structure, and a coating 34 and the coating 25 are inserted between the second structures 13, so that a direct contact between the metallic wires arranged between the strands 22 and between the first and second structures 12 and 13 is prevented. The metallic wires 21 substantially parallel to each other contact directly each other in the strands 22, and the metallic wires 31 and 32 substantially parallel to each other contact directly each other in the second structures 13. That is, in taking a broad view, not point contacts but line contacts are formed between the metallic wires. Therefore, pressures generated between surfaces of the metallic wires by the tension applied to the rope is decreased to restrain a decrease of the operating life caused by the fretting. On the other hand, in any case, the metallic wires are at least partially broken by repeated flexures of the rope during a long operating time period. In this case, since the metallic wires 32 arranged on the outer periphery of the rope have greater diameters or lower strengths in comparison with those of the metallic wires 21 and 31, the metallic wires 32 arranged on the outer periphery of the rope are at least partially broken prior to the metallic wires 21 and 31 irrespective of data spread in material strength and production. In other words, the metallic wires 32 are significantly differentiated from the metallic wires 21 and 31 in diameter or strength irrespective of various conditions.

[0024] In this case, if the metallic wires 32 are appropriately differentiated from the metallic wires 21 and 31 in fatigue strength with taking the fretting into consideration, a relationship between a residual operating life of the rope and a number of the metallic wires 32 broken prior to the metallic wires 21 and 31 is known. Therefore, by measuring the number of the broken metallic wires 32 arranged on the outer periphery of the rope, a strength of the rope is measurable. That is, when the rope should be replaced is easily known.

[0025] Fig. 2 is a cross sectional view showing a principle of detecting the breakage of the metallic wires 32. In Fig. 2, for convenience on explanation, the coatings 15 and 34 of the rope are imaginarily removed to expose the metallic wires 32. A breakage detector 50 includes two magnetic exiters 51 arranged along the rope and a magnetic device 52 for detecting a leakage magnetic flux from the rope. By energizing the exiters 51, a magnetism generated between the exiters 51 flows into the metallic wires 32 through the coating of the rope to generate a magnetic flux 53. When the breakage does not exist in the metallic wires 32, a magnetoresistance is constant in the rope so that the magnetic flux flows from one of the exiters 51 to the other of the exiters 51.

[0026] If a breakage portion 32a exists in the metallic wires 32 on the outer periphery of the rope as shown in the drawing, the magnetoresistance increases at the breakage portion 32a so that a magnetic flux 531 flows out of the rope. An amount of the leakage magnetic flux 531 out of the rope is in proportion to a degree of the magnetoresistance, that is, a number of the broken metallic wires 32. By measuring the leakage magnetic flux 531 with the magnetic device 52, not only the breakage of the metallic wires but also the number of the broken metallic wires is known. If the breakage of the metallic wires 32 not on the outer periphery of the rope exists, the magnetic flux passes the metallic wires arranged on an outside of the breakage of the metallic wires so that the amount of the leakage magnetic flux out of the rope is decreased. Therefore, it is difficult to detect the breakage with the magnetic device 52.

[0027] In the rope of the invention, as described above, when the breakage of the metallic wires starts after a long term of use, the breakage occurs on the metallic wires 32 on the outer periphery of the rope, so that the breakage of the metallic wires on the outer periphery of the rope is detectable magnetically. Further, the number of the broken metallic wires is measurable from the amount of the leakage magnetic flux. The residual strength of the rope and a future variation of the residual strength of the rope can be estimated on recorded data of the number of the broken metallic wires and the residual strength of the rope, so that a rope exchange timing can be easily determined.

[0028] Fig. 3 is a diagram showing a relationship between a number of bending times and a rope strength, and the rope strength decreases gradually in accordance with an increase of the number of bending times during the use of the rope. When the number of bending times increases to bending times N1 so that the breakage of the metallic wires 32 starts, the strength of the rope decreases rapidly. Thereafter, when the breakage of the metallic wires 21 and 32 starts (at bending times N2), the strength of the rope decreases abruptly. From the number of the broken metallic wires 32, the rope strength is known. Therefore, when the number of the broken metallic wires 32 reaches a predetermined value, the life of the rope is ended.

[0029] Fig. 4 shows a flow chart of these operation, and data of the relationship of Fig. 3 and frequency of use are recorded. From the above data and the number of the broken metallic wires detected by the deterioration measuring method as shown in Fig. 2, the residual strength of the rope is measured. On the other hand, when the breakage of the metallic wires has been started, a number of bending times in which the rope is safely usable continuously in future is determined on the number of the broken metallic wires, and the acceptable number of bending times is converted with the frequency of use to a number of days, so that the strength of the rope, the time period in which the rope is usable in future, a rope exchange timing and so forth are output.

[0030] Fig. 5 is a cross sectional view of the rope as another embodiment of the invention, and reference numerals commonly used between Figs. 1 and 5 denote common elements respectively. A difference between Figs. 1 and 5 is that the number of the metallic wires 32 breakable prior to the metallic wires 21 and 31 is decreased. The other structure is common with Fig. 1, whereby a detailed explanation is not done. In this case, a rate of [strength/cross sectional area] is increased. On the other hand, the number of the metallic wires 32 breakable in advance is decreased and an accuracy in data as shown in Fig. 3 is required, however, the same effect is obtainable.

[0031] Fig. 6 is a cross sectional view of the rope as another embodiment of the invention, and reference numerals commonly used between Figs. 1 and 6 denote common elements respectively. A difference between Figs. 1 and 6 is that the first structure 12 as the core includes the strands 22 in each of which the metallic wires 21 are twisted around the core 23, and the coating 25, and that the coating is deleted from the second structure 13. The other structure is common with Fig. 1, whereby a detailed explanation is not done. In this case, the metallic wires 21 in the first structure 12 can contact each other in parallel so that the life time of the rope is extensible. Further, since the second structure 13 does not need to be coated, a producing process can be cut down. In this case, the coating 15 is inserted between the strands adjacent to each other. On the other hand, the coating 15 and the inner structure 33 need to be adhered to each other by an adhesive. The metallic wires 32 as the object of the invention are breakable prior to the other metallic wires 21 and 31 to detect the deterioration of the rope, so that the same effect is obtainable.

[0032] Incidentally, although the metallic wires 32 breakable in advance are arrange on the outer periphery of the second structure in the above embodiments, the metallic wires breakable in advance may be arranged in a part of the metallic wires 21 of the first structure 12 or a part of the metallic wires 31 in the second structure 13 so that the purpose is achieved.

[0033] It should be further understood by those skilled in the art that although the foregoing description has been made on embodiments of the invention, the invention is not limited thereto and various changes and modifications may be made without departing from the spirit of the invention and the scope of the appended claims.

Claims

1. A method for detecting a damage of a rope including a bundle of wires (21, 31, 32), the method comprising the steps of:

generating a magnetic field in the bundle of wires (21, 31, 32), and
measuring a leakage of a magnetic flux from the bundle of wires (21, 31, 32) so that the damage of the rope is detected corresponding to a degree of the leakage of the magnetic flux.

2. The method of claim 1, wherein the magnetic flux extends longitudinally in the bundle of wires (21, 31, 32).

3. An apparatus for detecting a damage of a rope including a bundle of wires (21, 31, 32), the apparatus comprising:

a pair of magnetic cores (51) magnetizable to generate a magnetic field in the bundle of wires (21, 31, 32), and
a magnetic sensor (52) for measuring a leakage of a magnetic flux from the bundle of wires (21, 31, 32) so that the damage of the rope is detected corresponding to a degree of the leakage of the magnetic flux.

4. The apparatus of claim 3, wherein the magnetic cores (51) are spaced apart from each other in a longitudinal direction of the bundle of wires (21, 31, 32) to generate the magnetic flux extending longitudinally in the bundle of wires (21, 31, 32), and the magnetic sensor (52) is adapted to measure the leakage of the magnetic flux at a position between the magnetic cores (51) in the longitudinal direction.

FIG. 1

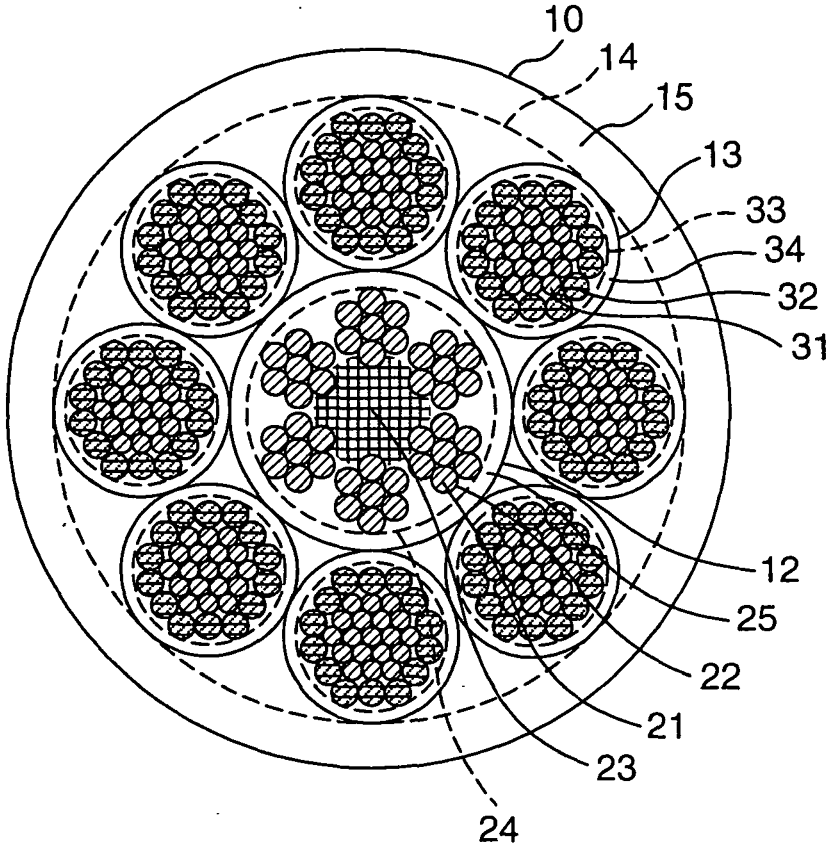
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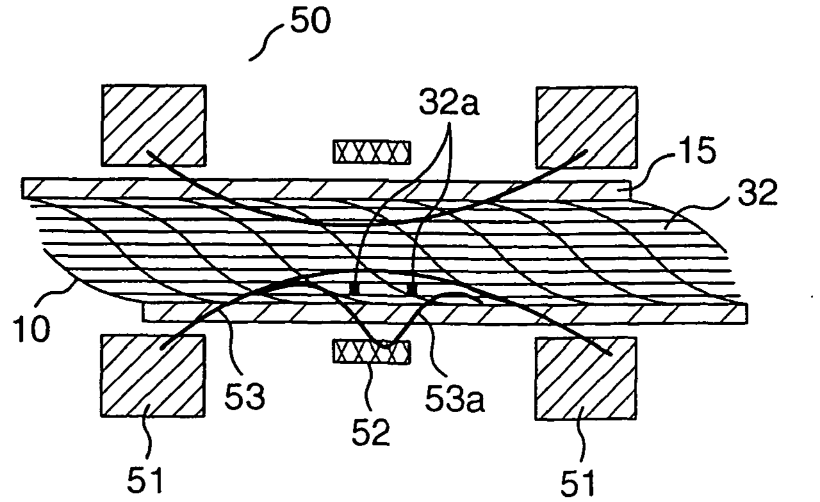
FIG. 2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32a
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52
53a
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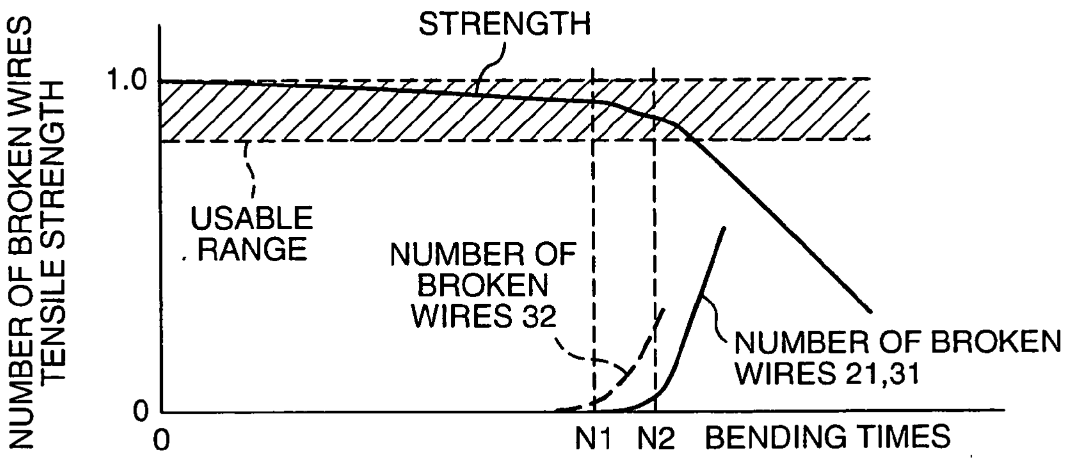
51

FIG. 3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NUMBER OF BROKEN WIRES 21,31
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N1
N2
BENDING TIMES

FIG. 4

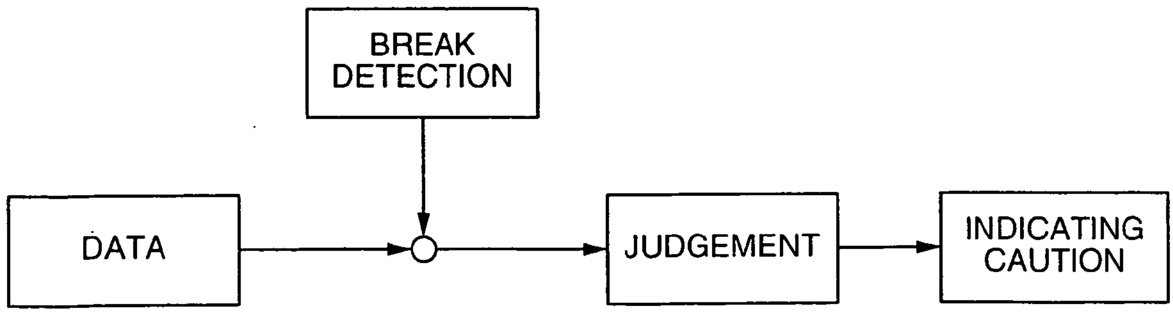
BREAK DETECTION
DATA
JUDGEMENT
INDICATING CAUTION

FIG. 5

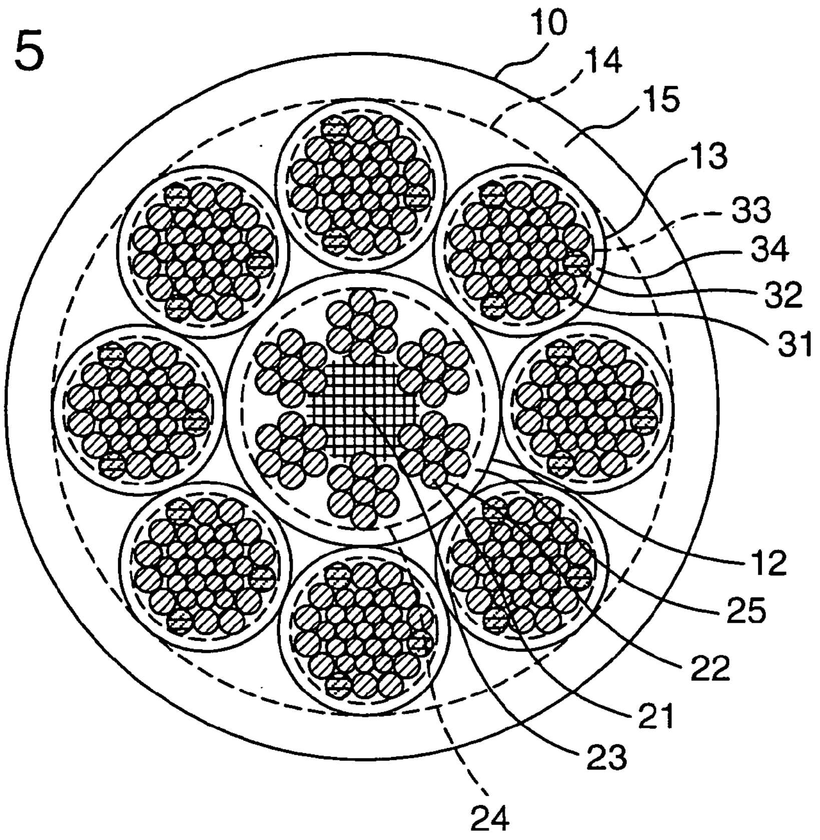
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FIG. 6

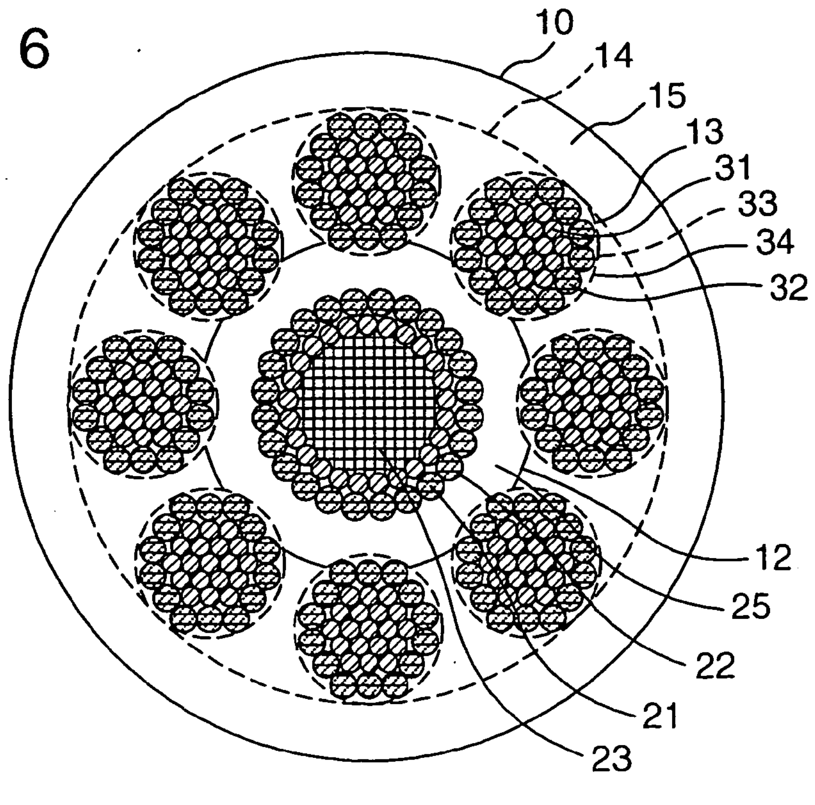
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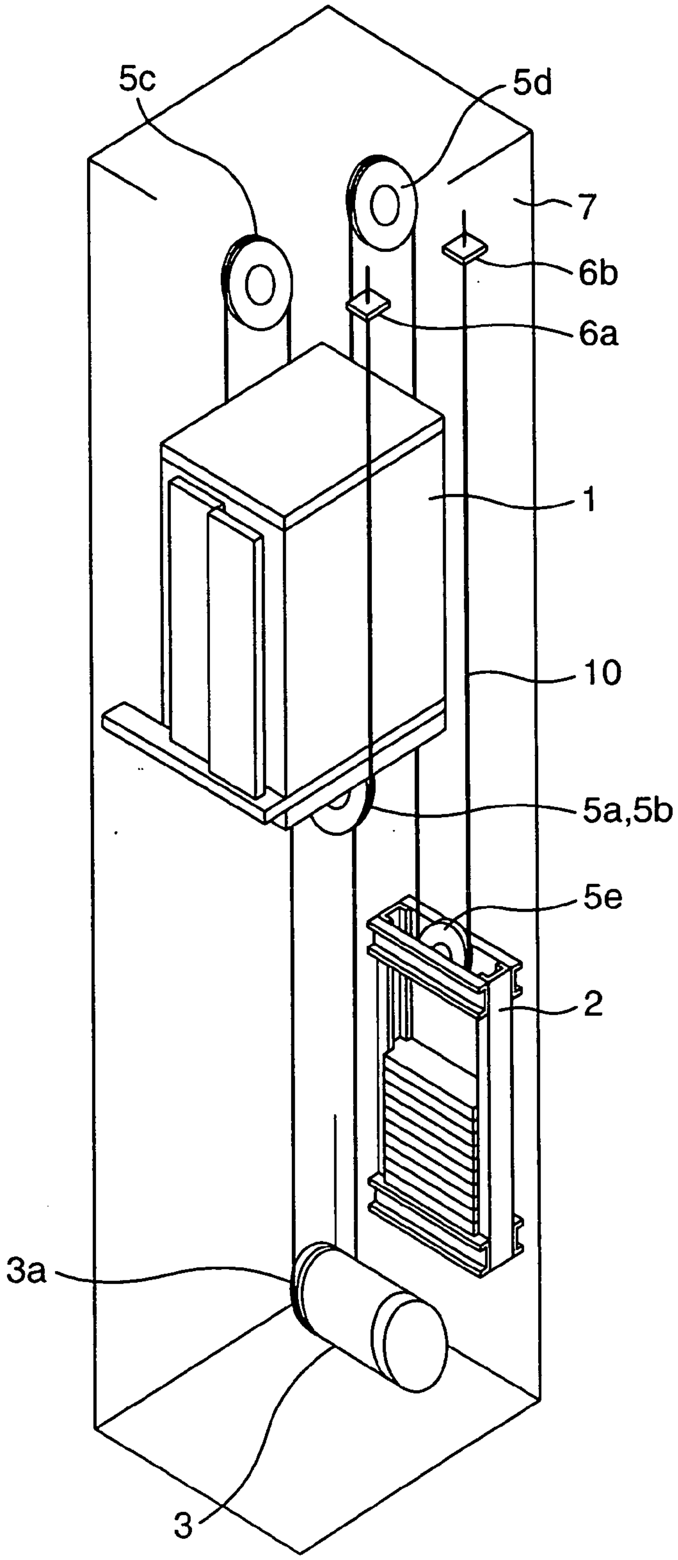
FIG. 7



European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 07 00 7092

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	FR 2 405 483 A (PLESSEY HANDEL UND INVESTMENTS AG) 4 May 1979 (1979-05-04) * page 6, line 23 - page 7, line 16 * * page 8, line 18 - line 24 * -----	1-4	INV. D07B1/06
X	GB 2 206 969 A (COAL INDUSTRY (PATENTS) LIMITED) 18 January 1989 (1989-01-18) * the whole document * -----	1-4	
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TECHNICAL FIELDS SEARCHED (IPC)

D07B
B66B
G01N

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	20 June 2007	Stroppa, Giovanni

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

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EPO FORM 1503 03.82 (P04C01)

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 07 00 7092

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
The members are as contained in the European Patent Office EDP file on
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20-06-2007

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EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

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- JP 8261972 A **[0002]**
- JP 2001302135 A **[0003]**