Rope of a hoisting apparatus, more particularly of a passenger elevator, which comprises a plurality of parts (Tl, T2), which continue unbroken for essentially the whole length of the rope, which parts are preferably load-bearing parts. At least one (T2) of the aforementioned parts (Tl, T2) is arranged to be essentially more susceptible to breakage in relation to the number of bends than the other (Tl) aforementioned parts.
ROPE OF A HOISTING APPARATUS, ROPE ARRANGEMENT, ELEVATOR AND METHOD

FIELD OF THE INVENTION

The object of the present invention is the rope of a hoisting apparatus as defined in the preamble of claim 1, a rope arrangement as defined in the preamble of claim 12, an elevator as defined in the preamble of claim 22, and a method as defined in the preamble of claim 25.

BACKGROUND OF THE INVENTION

The elevator car of an elevator is most generally moved with hoisting roping, which comprises one or more ropes. To ensure safety and availability, the hoisting roping must be kept in good condition. The hoisting roping is most generally fixed at its ends to the building and/or to the elevator car and to the counterweight, depending on the suspension ratio and otherwise on the type of reeving. In connection with the operation of the elevator, the hoisting roping with its rope(s) move(s) as the elevator car moves. The speed of movement of the elevator car and of the hoisting ropes is most generally controlled with a traction sheave, and the hoisting ropes are also guided to pass along the desired route by means of diverting pulleys. Wear is caused in the hoisting ropes over time owing to, among other things, fatigue produced by their guidance and traction sheave contact as well as by repeated bending and tensile stress.

It is known in the art that the condition of prior-art ropes can be assessed visually. One problem, among others, is that it has been necessary to assess the condition of all the ropes separately. Problems have also been caused by the fact that it has been awkward to visually observe the condition of coated ropes. Various condition monitoring
apparatuses have aimed to overcome this problem, but they have been complex and expensive to implement.

OBJECT OF THE INVENTION

The aim of the invention is to eliminate, among others, the aforementioned drawbacks of prior-art solutions. More particularly the aim of the invention is to facilitate the condition monitoring of the ropes of a hoisting apparatus, more particularly of a passenger elevator.

The aim of the invention is to achieve one or more of the following advantages, among others:

- A safe rope and elevator are achieved, the roping of which is safe.
- An efficient condition monitoring method is achieved.
- A rope, rope arrangement of an elevator, elevator and method are achieved that are advantageous from the viewpoint of condition monitoring.
- A rope is achieved that is light and of high tensile strength and tensile rigidity with respect to its dead weight.
- An elevator and the rope of an elevator are achieved, the tolerance to high temperatures of which is better than before.
- A rope is achieved that possesses high thermal conductivity combined with a high operating temperature.
- A rope is achieved that has a simple, belt-like structure and that is simple to manufacture.
- A rope is achieved that comprises one straight or a number of parallel straight load-bearing parts, in which case the behavior in bending is advantageous.
- An elevator is achieved, the roping of which is light.
- An elevator and the rope of an elevator are achieved, in which the moving and accelerating masses as well as the shaft loads are smaller than before.
- An elevator and a rope are achieved, in which there is not discontinuity or intermittency of the rope, owing to which the rope of the elevator is quiet and advantageous in terms of vibration.
- A rope is achieved that has little internal wear.
- A rope is achieved that has good resistance to high temperature and good thermal conductivity.
- A rope is achieved that has good fatigue endurance.

In elevator systems the elevator car, the counterweight, or both, can be supported and/or moved safely with the rope according to the invention. The rope according to the invention is applicable for use in both elevators provided with a counterweight and without a counterweight. The rope and/or method according to the invention can also be used in connection with other hoisting apparatuses, e.g. for the condition monitoring of the ropes of cranes. The lightness of the rope is useful, especially in accelerating situations, because the energy required by changes in the speed of the rope depends on its mass. In addition, lightness makes handling of the ropes easier.

**SUMMARY OF THE INVENTION**

The hoisting rope of the hoisting apparatus according to the invention can be said to be characterized by what is disclosed in the characterization part of claim 1. The rope arrangement according to the invention can be said to be characterized by what is disclosed in the characterization part of claim 12. The elevator according to the invention can be said to be characterized by what is disclosed in the characterization part of claim 22. The method according to the invention can be said to be characterized by what is disclosed in the characterization part of claim 25. Other
embodiments of the invention are characterized by what is disclosed in the other claims. Some inventive embodiments are also discussed in the descriptive section and in the drawings of the present application. The inventive content of the application can also be defined differently than in the claims presented below. The inventive content may also consist of several separate inventions, especially if the invention is considered in the light of expressions or implicit sub-tasks or from the point of view of advantages or categories of advantages achieved. In this case, some of the attributes contained in the claims below may be superfluous from the point of view of separate inventive concepts. The features of the various embodiments of the invention can be applied within the framework of the basic inventive concept in conjunction with other embodiments.

According to the invention the rope of a hoisting apparatus, more particularly of a passenger elevator, comprises a plurality of parts, which continue unbroken for essentially the whole length of the rope, which parts are preferably load-bearing parts. At least one of the aforementioned parts is arranged to be essentially more susceptible to breakage in relation to the number of bends than the other aforementioned parts.

In one embodiment of the invention at least one of the aforementioned parts is arranged to be essentially more susceptible to breakage in relation to the number of bends than the other aforementioned parts by arranging it to be more susceptible to breakage in its cross-sectional shape and dimensions than the other aforementioned parts. The part that is susceptible to breakage and the others of the aforementioned parts are essentially of the same material.

In one embodiment of the invention the rope comprises a plurality of load-bearing parts in the longitudinal
direction of the rope, which parts are distributed in the rope at a distance from each other in the width direction of the rope, and which rope can be bent around the neutral axis of the width direction of the rope, and that the rope comprises at least one load-bearing part that extends in the thickness direction of the rope to a first distance from the neutral axis of the width direction of the rope and at least one load-bearing part that extends to a second distance from the neutral axis of the width direction of the rope, which second distance is greater than the first distance.

In one embodiment of the invention the width of the rope is greater than the thickness.

In one embodiment of the invention the tensile strengths and/or the moduluses of elasticity of the load-bearing part that is susceptible to breakage and of at least some, preferably all, of the other load-bearing parts are dimensioned to be essentially the same.

In one embodiment of the invention the cross-sectional surface areas of the load-bearing part that is susceptible to breakage and of at least some, preferably all, of the other load-bearing parts are essentially the same.

In one embodiment of the invention the width of the part that is susceptible to breakage is smaller and the thickness of the part that is susceptible to breakage is greater than at least one of the other load-bearing parts of the rope.

In one embodiment of the invention at least the part that is susceptible to breakage is visible outside the rope, preferably owing to the transparency of the coating binding the load-bearing parts to each other.
In one embodiment of the invention at least one of the aforementioned parts is arranged to be essentially more susceptible to breakage in relation to the number of bends than the other parts by manufacturing the part that is susceptible to breakage from a material that withstands bending worse than the material from which the other parts are manufactured or by arranging an initial defect in the part susceptible to breakage, such as e.g. a transverse groove.

In one embodiment of the invention the load-bearing parts of the rope are of essentially the same material, preferably of completely the same material.

In one embodiment of the invention the aforementioned load-bearing parts are of composite and one of the load-bearing composite parts comprises a wire inside it that is situated in the proximity of the surface of the load-bearing part in question, as viewed in the thickness direction of the rope, and is manufactured from a material that endures bendings worse than the other material of the part in question.

According to the invention the rope arrangement of a hoisting apparatus, more particularly of a passenger elevator, comprises a plurality of ropes, which are arranged to move the elevator car e.g. by means of a traction sheave. At least one of the aforementioned ropes is arranged to be essentially more susceptible to breakage in relation to the number of bends than the other parts.

In one embodiment of the invention one of the aforementioned ropes is arranged to be essentially more susceptible to breakage in relation to the number of bends than the other aforementioned ropes by arranging it to be more susceptible to breakage in terms of the cross-
sectional shape and cross-sectional dimensions of the load-bearing part than the other aforementioned ropes. The load-bearing parts of the rope that is susceptible to breakage and the load-bearing parts of the other aforementioned ropes are preferably of the same material.

In a more refined embodiment of the concept of the invention, the width/thickness of the rope is at least 2 or more, preferably at least 4, or even 5 or more, or even 6 or more, or even 7 or more or—even 8 or more. In this way good power transmission capability is achieved with a small bending radius. This can be implemented preferably with composite material presented in this patent application, which has a very advantageously large width/thickness ratio owing to its rigidity.

In a more refined embodiment of the concept of the invention, the width of each aforementioned power transmission part is greater than the thickness, preferably such that the width/thickness of each aforementioned power transmission part is at least 1.3 or more, or even 2 or more, or even 3 or more, or even 4 or more, or even 5 or more. In this way a wide rope can be formed simply and to be thin.

In one embodiment of the invention the plurality mentioned in the rope arrangement comprises a plurality of ropes, of which each rope can be bent around the neutral axis of the width direction of the rope. The rope that is susceptible to breakage comprises at least one load-bearing part that extends in the thickness direction of the rope to a second distance from the neutral axis of the width direction of the rope, and that the load-bearing parts of the other ropes extend at most in the thickness direction of the rope to a first distance from the neutral axis of the width direction of the rope, which first distance is smaller than the second distance.
In one embodiment of the invention the aforementioned load-bearing parts of the aforementioned rope or rope arrangement are of composite material, which composite material comprises reinforcing fibers, which are preferably of carbon fiber or glass fiber, embedded into a polymer matrix.

In one embodiment of the invention the aforementioned reinforcing fibers of the aforementioned rope or rope arrangement are essentially electrically conductive. Thus the condition of the load-bearing part can be monitored by monitoring changes in one of its electrical properties.

In one embodiment of the invention the aforementioned reinforcing fibers of the aforementioned rope or rope arrangement are non-metallic, preferably synthetic fibers. Thus the fibers and the rope formed by means of them are light.

In one embodiment of the invention the density of the aforementioned reinforcing fibers \((F)\) of the aforementioned rope or rope arrangement is less than 4000kg/m3, and the strength is over 1500 N/mm2, more preferably so that the density of the aforementioned fibers \((F)\) is less than 4000kg/m3, and the strength is over 2500 N/mm2, most preferably so that the density of the aforementioned fibers \((F)\) is less than 3000kg/m3, and the strength is over 3000 N/mm2. One advantage is that the fibers are light, and not many of them are needed because they are strong.

In one embodiment of the invention the load-bearing part of the aforementioned rope or rope arrangement is a solid elongated rod-like piece.
In one embodiment of the invention the load-bearing part of the aforementioned rope or rope arrangement is parallel with the longitudinal direction of the rope.

In one embodiment of the invention the structure of the aforementioned rope or the rope of the aforementioned rope arrangement continues essentially the same for the whole distance of the rope.

In one embodiment of the invention the aforementioned reinforcing fibers are in the longitudinal direction of the rope.

In one embodiment of the invention the individual reinforcing fibers are homogeneously distributed in the aforementioned matrix.

In one embodiment of the invention the aforementioned reinforcing fibers are continuous fibers in the longitudinal direction of the rope, which fibers preferably continue for the whole length of the rope.

In one embodiment of the invention the aforementioned reinforcing fibers are bound into a uniform load-bearing part with the aforementioned polymer matrix, preferably in the manufacturing phase by embedding the reinforcing fibers into the material of the polymer matrix.

In one embodiment of the invention the aforementioned load-bearing part comprises straight reinforcing fibers parallel with the longitudinal direction of the rope, which fibers are bound into a uniform part with the polymer matrix.

In one embodiment of the invention essentially all the reinforcing fibers of the aforementioned load-bearing part are in the longitudinal direction of the rope.
In one embodiment of the invention the structure of the load-bearing part continues essentially the same for the whole distance of the rope.

In one embodiment of the invention the polymer matrix is of a non-elastomer.

In one embodiment of the invention the module of elasticity ($E$) of the polymer matrix ($M$) is over 2 GPa, most preferably over 2.5 GPa, and further preferably in the range 2.5-10 GPa, most preferably of all in the range 2.5-3.5 GPa.

In one embodiment of the invention the polymer matrix comprises epoxy, polyester, phenolic plastic or vinyl ester.

In one embodiment of the invention over 50% of the surface area of the cross-section of the load-bearing part is of the aforementioned reinforcing fiber, preferably such that 50%-80% is of the aforementioned reinforcing fiber, more preferably such that 55%-70% is of the aforementioned reinforcing fiber, most preferably such that approx. 60% of the surface area is of the reinforcing fiber and approx. 40% is of the matrix material.

In one embodiment of the invention the reinforcing fibers together with the matrix form a uniform load-bearing part, inside which relative abrasive movement among the fibers or between the fibers and the matrix does not essentially occur.

In one embodiment of the invention the width of the load-bearing part is greater than the thickness of the rope in the transverse direction.
In one embodiment of the invention the rope comprises a plurality of the aforementioned load-bearing parts side by side.

In one embodiment of the invention the load-bearing part is surrounded with a polymer layer (1), which is preferably an elastomer, most preferably a high-friction elastomer such as e.g. polyurethane.

In one embodiment of the invention the load-bearing part(s) cover most of the cross-section of the rope.

In one embodiment of the invention the load-bearing part is composed of the aforementioned polymer matrix, reinforcing fibers bound to each other by the polymer matrix, and also possibly a coating around the fibers, and also possibly additives mixed into the polymer matrix.

In one embodiment of the invention the structure of the rope continues essentially the same for the whole distance of the rope and in that the rope comprises a wide and at least essentially flat, preferably fully flat, side surface for enabling power transmission based on friction via the aforementioned wide surface.

According to the invention, the elevator, preferably a passenger elevator, comprises an elevator car, a traction sheave, and a power source for rotating the traction sheave. It comprises one of the types of rope described earlier and/or one of the types of rope arrangement described earlier. The elevator car is arranged to be moved by means of the aforementioned rope and/or rope arrangement.
In one embodiment of the invention the rope and/or rope arrangement is arranged to move an elevator car and a counterweight.

In one embodiment of the invention the elevator comprises means for monitoring the condition of the part of the rope that is susceptible to breakage, which means monitor, of the load-bearing parts of the rope, preferably only the condition of the aforementioned part of the rope that is susceptible to breakage.

According to the invention, in the method for monitoring the condition of a rope and/or of roping, which rope and/or roping comprises a plurality of load-bearing parts, some, preferably one, of the load-bearing parts is/are arranged to be more susceptible to breakage in relation to the number of bends than the other load-bearing parts, and in the method the condition of the load-bearing part that is most susceptible to breakage is monitored.

In one embodiment of the invention, in the method the condition of all the load-bearing parts is not monitored. It is advantageous that the condition of the load-bearing parts other than that/those arranged to be susceptible to breakage is not monitored either at all or at least not in the same way (e.g. a change in electrical property) as the condition of a part that is susceptible to breakage.

In one embodiment of the invention the rope and/or roping is according to an earlier claim.

In one embodiment of the invention, in the method the condition of the rope and/or of the rope arrangement is monitored by monitoring the condition of a part or parts that is/are susceptible to breakage in one of the following ways
by observing visually changes that have occurred in the part that is susceptible to breakage,
- by observing changes in the magnetic field,
- on the basis of an electrical property of the sacrificial part, e.g. on the basis of a change in an electrical property of the sacrificial part, such as e.g. on the basis of a change in resistance, e.g. by deducing a change in the condition of the sacrificial wire from a change in an electrical property.

In one embodiment of the invention, in the method the condition of the rope and/or of the roping is monitored by monitoring the condition of a part or parts that is/are susceptible to breakage, and if it is detected that a part susceptible to breakage has broken or the condition of it has fallen to below a certain predefined level, a need to replace or overhaul the rope or ropes is diagnosed and rope replacement work or rope maintenance work is started.

In one embodiment of the invention, in the method the condition of the rope and/or of the roping is monitored by monitoring changes in an electrical property of the part or the parts that is/are susceptible to breakage, such as e.g. on the basis of a change in resistance, e.g. by deducing a change in the condition of the sacrificial wire from a change in an electrical property. In one embodiment of the invention the tension produced by the weight of the elevator car/counterweight is transmitted along at least one of the aforementioned parts from the elevator car/counterweight at least to the traction sheave.

In one embodiment of the invention at least one of the aforementioned parts is arranged to be essentially more susceptible to breakage in relation to the number of bends than the other aforementioned parts by arranging it to be
more susceptible to breakage in its cross-sectional shape and dimensions than the other aforementioned parts, and the part that is susceptible to breakage and the others of the aforementioned parts are of the same material.

LIST OF FIGURES
In the following, the invention will be described in detail by the aid of some examples of its embodiments with reference to the attached drawings, wherein

Fig. 1 presents a diagrammatic cross-section of a rope according to one embodiment of the invention.

Fig. 2 presents a diagrammatic cross-section of a rope according to another embodiment of the invention.

Fig. 3 presents one diagrammatic embodiment of a rope arrangement according to the invention.

Fig. 4 presents a diagrammatic cross-section of a rope according to one embodiment of the invention.

Fig. 5 presents a diagrammatic cross-section of a rope according to another embodiment of the invention.

Fig. 6 presents a diagrammatic magnified detail of a cross-section of a rope according to the invention.

Fig. 7 presents one embodiment of the elevator according to the invention.

DETAILED DESCRIPTION OF THE INVENTION

Fig. 1 presents a diagrammatic cross-section of a rope according to one embodiment of the invention, as viewed from the longitudinal direction of the rope. The rope comprises a plurality of load-bearing parts (T1, T2), which continue unbroken for essentially the whole length of the rope. One (T2) of the aforementioned load-bearing parts
(T1, T2) is arranged to be essentially more susceptible to breakage in relation to the number of bends than the other load-bearing parts T1 of the rope 10 in question. This is achieved by means of the structure of the rope. When bending a rope 10 that is at rest (in the figure, up or down) in its thickness direction it bends around an internal neutral axis, on the first side of which axis compressive stress occurs and on the second side tensile stress; the aforementioned stresses are caused in particular in the load-bearing parts of the rope. Susceptibility to breakage for the part T2 is particularly brought about by forming the rope 10 such that the part T2 of the rope 10 that is most susceptible to breakage (hereinafter part that is susceptible to breakage) extends to a distance (S2, S2') from the neutral axis of the width direction of the rope, which distance is greater than the distance (S1, S1') to which the other load-bearing parts (T1) extend in the thickness direction of the rope from the neutral axis N of the width direction of the rope. In this case when bending the rope, e.g. around a diverting pulley, the outermost structures of the part T2 that is susceptible to breakage are subjected to greater bending stresses (tension/compression, depending on the direction of bending) than the structures of the other load-bearing parts. Owing to the structure, the outermost parts (from the axis N) of the part T2 that is susceptible to breakage undergo greater stretching in bending than the other load-bearing parts of the rope. For these reasons, the part T2 is the part of the rope that is most susceptible to breakage in relation to the number of times it bends. Arranging a part that is susceptible to breakage in the rope makes it possible to determine the condition of the rope by inspecting the condition of the part that is susceptible to breakage without also separately inspecting all the other load-bearing parts.
The tensile strengths and/or the modulus of elasticity of all the other load-bearing parts of the part T2 that is susceptible to breakage are dimensioned to be essentially the same. The rope is thus simple to manufacture so that it possesses a symmetrical structure in terms of its strength properties in the width direction of the rope when a tensile load in the longitudinal direction of the rope is exerted on the straight rope. In other words, there are no essential differences in the behavior of the load-bearing parts when a longitudinal tensile load is exerted on the straight rope. The load-bearing parts are distributed in the rope 10 at a distance from each other in the width direction of the rope. The load-bearing parts T1, T1', T2, T2' are connected to each other with a polymer c.

The polymer forms a coating that binds the load-bearing parts to each other and surrounds the load-bearing parts and is preferably of polyurethane.

The rope presented in Fig. 2 is otherwise similar to the rope of Fig. 1 but differs in the placement of the part that is susceptible to breakage and in the shape of the surface structure of the rope. The rope 20 comprises a protrusion extending in the thickness direction of the rope 20, which protrusion can be used to guide the rope on the traction sheave 23 in the width direction of the rope in the groove of the traction sheave 23, the shape of which groove preferably corresponds to the shape of the protrusion 21. The protrusion continues essentially the same for the whole distance of the rope and is formed by means of the polymer coating c of the load-bearing rope.

The protrusion is formed preferably in the width direction w at the point of the part that is susceptible to breakage, preferably so that the protrusion 21 is wider in the width direction than the part W2' that is susceptible to breakage. The aforementioned protrusion is preferably in...
the center of the rope in the width direction w of the rope.

The ropes presented in Figs. 1 and 2 are such that their structure preferably continues essentially the same for the whole distance of the rope, but not necessarily because it is possible, if desired, to arrange for the cross-section to change intermittently, e.g. as toothing (e.g. a protrusion 21). The rope 10, 20 is belt-like, i.e. the rope possesses in the first direction t, which is at a right angle to the longitudinal direction of the rope, a measured thickness, and in the other direction w, which is at a right angle to the longitudinal direction of the rope and to the aforementioned first direction, a measured width, which width is essentially greater than the aforementioned thickness. The width of the rope is thus essentially greater than the thickness. In order for the rope 10,20 to possess a symmetrical structure in terms of its strength properties in the width direction w of the rope when a tensile load in the longitudinal direction of the rope is exerted on the straight rope, the cross-sectional surface areas of the part T2,T2' that is susceptible to breakage and of at least some, preferably all, of the other load-bearing parts T1,T1' are essentially the same. This can be achieved simply such that the width (W2,W2') of the part that is susceptible to breakage is smaller and the thickness (S2,S2;) of the part that is susceptible to breakage is greater than the other load-bearing parts of the rope. In this case the part T2,T2' that is susceptible to breakage and the other load-bearing parts (T1,T2,T1',T2') are of essentially the same material, preferably of completely the same material or for other reasons the strength properties of them, more particularly those of the material in the longitudinal direction of the rope, are essentially the same. In order for the condition of the rope to be easy to inspect, the part that is
susceptible to breakage is preferably visible outside the rope, preferably owing to the transparency of the coating binding the load-bearing parts to each other.

Fig. 3 presents a rope arrangement according to the invention for a passenger elevator, which arrangement comprises a plurality of ropes (30, 31), which are arranged to move the elevator car (not shown) when driven by the traction sheave 33. One 30 of the aforementioned ropes (30, 31) is arranged to be essentially more susceptible to breakage in relation to the number of bends than the other ropes 31. Susceptibility to breakage is brought about in the rope 30 by forming the rope 30 such that the load-bearing part T2''' of it that is most susceptible to breakage extends to a distance (S2''') from the neutral axis of the width direction of the rope, which distance is greater than the distance (S1'') to which the load-bearing parts (T1'''') of the other ropes 31 extend in the thickness direction of the rope from the neutral axis N of the width direction of each rope. The ropes 30, 31 experience essentially similar bending in connection with operation, e.g. they pass preferably along the same route in connection with the operation of the elevator. They are parallel in the width direction of the ropes, which is essentially the direction in which their neutral axis is aligned. The embodiment presented differs from the embodiments of Figs. 1 and 2 in that the part T2''' that is most susceptible to breakage is in a different rope than T1'''', but otherwise the principles described in connection with Figs. 1 and 2 apply also to this embodiment, e.g. with respect to materials. The parts T2''' and T1''' are preferably of composite as described elsewhere in this patent application, e.g. according to Fig. 6. In the arrangement presented, the condition of the rope 30 is monitored, which is the most susceptible to breakage of the ropes 30, 31, and therefore the condition of the ropes 31 does not need to be monitored.
Fig. 4 presents a cross-section of a rope according to a third embodiment of the invention, and at the same time a second method to arrange a part in the rope that is more susceptible to breakage than the other load-bearing parts. In the rope 40 presented, the part T2''' that is susceptible to breakage is brought about by arranging an initial defect in one of the load-bearing parts T1''', T2''', in the solution presented a transverse groove 41. The transverse grooves can be at a distance from each other in the longitudinal direction of the rope. A third method to arrange a part in the rope that is more susceptible to breakage than the other load-bearing parts would be to form the part intended to be susceptible to breakage from a material that withstands bending worse than the material from which the other parts are manufactured. In this case the dimensions and placement of the load-bearing parts in relation to the neutral axis are preferably similar.

Fig. 5 presents a cross-section of a rope 50 according to a third embodiment of the invention, and at the same time a second method to arrange a part T2''' in the rope that is more susceptible to breakage than the other load-bearing parts T1'''. One of the load-bearing composite parts comprises a wire T inside it that is situated in the proximity of the surface of the load-bearing part in question, in the thickness direction of the rope, and is manufactured from a material that endures bendings worse than the other material of the part T2''' in question. For example, when the other material is carbon composite or glass fiber composite (polymer matrix), the material of the wire T can be metal, e.g. copper or steel or other suitable metal. From the condition of the wire in question, the condition of the rope 50 can be deduced. The wire continues unbroken for essentially the whole length of the rope, and
rupture or breakage of the wire T can be detected e.g. visually or as a change in an electrical property caused by the breakage, e.g. from a change in resistance or in the magnetic field with e.g. means described elsewhere in this patent application. The load-bearing parts presented are preferably wire in terms of their material, except for those types presented in Figs. 1 and 2.

The load-bearing parts (T1, T1', T1'', T1''', T2, T2', T2'', T2''', T2''') of the ropes/roping (10, 20, 30, 40, 50, R) presented are preferably of non-metallic fiber composite, which comprises carbon fibers or glass fibers, preferably carbon fibers, in a polymer matrix. The load-bearing parts with their fibers are longitudinal to the rope, for which reason the rope retains its structure when bending. Individual fibers are most preferably oriented essentially in the longitudinal direction of the rope. In this case the fibers are aligned with the force when the rope is pulled. The aforementioned reinforcing fibers are bound into a uniform load-bearing part with the aforementioned polymer matrix. Thus the aforementioned load-bearing part is one solid elongated rod-like piece. The aforementioned reinforcing fibers are preferably long continuous fibers in the longitudinal direction of the rope, which fibers preferably continue for the whole length of the rope. Preferably as many fibers as possible, most preferably essentially all the reinforcing fibers of the aforementioned load-bearing part are in the longitudinal direction of the rope. The reinforcing fibers are thus preferably essentially uninterlaced with relation to each other. Thus the cross-sectional structure of the load-bearing part can be made to continue as similar as possible for the whole distance of the rope. The aforementioned reinforcing fibers are distributed in the aforementioned load-bearing part as evenly as possible, so that the load-
bearing part would be as homogeneous as possible in the transverse direction of the rope.

The matrix surrounding the reinforcing fibers keeps the interpositioning of the reinforcing fibers essentially unchanged. It equalizes with its slight elasticity the distribution of a force exerted on the fibers, reduces fiber-fiber contacts and internal wear of the rope, thus improving the service life of the rope. Possible longitudinal movement between the fibers is elastic shearing exerted on the matrix, but in bending it is mainly a question of the stretching of all the materials of the composite part and not of their movement in relation to each other. The reinforcing fibers are most preferably of carbon fiber, with which good tensile rigidity and a light structure and good thermal properties, among other things, are achieved. Alternatively glass fiber reinforcement, with which, among other things, better electrical insulation is obtained, are suited to some applications. In this case also the tensile rigidity of the rope is slightly lower, so that traction sheaves of small diameter can be used. The composite matrix, in which the individual fibers are distributed as homogeneously as possible, is most preferably of epoxy resin, which has good adhesiveness to the reinforcements and which is strong to behave advantageously with glass fiber and carbon fiber. Alternatively, e.g. polyester or vinyl ester can be used. Most preferably the load-bearing composite part comprises approx. 60% carbon fiber and 40% epoxy resin.

In this application a load-bearing part refers to such a part of a rope that bears a significant portion of the load in the longitudinal direction of the rope exerted on the rope in question, e.g. of the load exerted on the rope by the elevator car and/or the counterweight supported by the rope. A load causes tension on the load-bearing part in the longitudinal direction of the rope, which tension is transmitted onwards in the longitudinal direction of the
rope inside the load-bearing part in question. Thus the load-bearing part can e.g. transmit force exerted on the rope by the traction sheave in the longitudinal direction of the rope to the counterweight and/or to the elevator car in order to move them. For example, in Fig. 7, where the counterweight 6 and the elevator car 3 are suspended on the rope, more precisely on the load-bearing part of the rope, which load bearing part extends from the elevator car 3 to the counterweight 6. The rope (20, 30, 31, 40, 50) is fixed to the counterweight and to the elevator car. The tension produced by the weight of the counterweight/elevator car is transmitted from the fixing along the load-bearing part of the rope from the counterweight/elevator car upwards at least to the traction sheave 2.

The reinforcing fibers of the load-bearing part are preferably essentially all of one and the same material.

Fig. 6 presents a preferred structure for a load-bearing part (T1, T1', T1'', T1''', T2, T2', T2'', T2''', T2'''''). A partial cross-section of the surface structure of the load-bearing part (as viewed in the longitudinal direction of the rope) is presented inside the circle in the figure, according to which cross-section the reinforcing fibers of the load-bearing parts presented elsewhere in this application are preferably in a polymer matrix. The figure presents how the reinforcing fibers F are essentially evenly distributed in the polymer matrix M, which surrounds the fibers and which is fixed to the fibers. The polymer matrix M fills the areas between the reinforcing fibers F and binds essentially all the reinforcing fibers F that are inside the matrix to each other as a uniform solid substance. In this case relative abrasive movement between the reinforcing fibers F and abrasive movement between the reinforcing fibers F and the matrix M is essentially prevented. A chemical bond exists between, preferably all, the individual reinforcing fibers F and the matrix M, one
advantage of which is uniformity of the structure. To strengthen the chemical bond, there can be, but not necessarily, a coating (not presented) between the reinforcing fibers and the polymer matrix M. The polymer matrix M is of the type described elsewhere in this application and can thus comprise additives for fine-tuning the properties of the matrix as an addition to the base polymer. The polymer matrix M is preferably of a hard non-elastomer. The fact that the reinforcing fibers are in the polymer matrix in the load-bearing part means that in the invention the individual reinforcing fibers are bound to each other with a polymer matrix e.g. in the manufacturing phase by embedding them into the material of the polymer matrix. In this case the gaps of individual reinforcing fibers bound to each other with the polymer matrix comprise the polymer of the matrix. Thus in the invention preferably a large amount of reinforcing fibers bound to each other in the longitudinal direction of the rope are distributed in the polymer matrix. The reinforcing fibers are preferably distributed essentially evenly, i.e. homogeneously, in the polymer matrix such that the load-bearing part is as homogeneous as possible when viewed in the direction of the cross-section of the rope. In other words, the fiber density in the cross-section of the load-bearing part does not therefore vary greatly. The reinforcing fibers together with the matrix form a uniform load-bearing part, inside which relative abrasive movement does not occur when the rope is bent. The individual reinforcing fibers of the load-bearing part are mainly surrounded with the polymer matrix, but fiber-fiber contacts can occur in places because controlling the position of the fibers in relation to each other in the simultaneous impregnation with the polymer matrix is difficult, and on the other hand totally perfect elimination of random fiber-fiber contacts is not wholly necessary from the viewpoint of the functioning of the invention. If, however, it is desired to reduce their random occurrence, the individual reinforcing fibers can be
pre-coated such that a polymer coating is around them already before the binding of individual reinforcing fibers to each other. In the invention the individual reinforcing fibers of the load-bearing part can comprise material of the polymer matrix around them such that the polymer matrix is immediately against the reinforcing fiber but alternatively a thin coating of the reinforcing fiber, e.g. a primer arranged on the surface of the reinforcing fiber in the manufacturing phase to improve chemical adhesion to the matrix material, can be in between. Individual reinforcing fibers are distributed evenly in the load-bearing part such that the gaps of individual reinforcing fibers comprise the polymer of the matrix. Preferably the majority of the gaps of the individual reinforcing fibers in the load-bearing part are filled with the polymer of the matrix. Most preferably essentially all of the gaps of the individual reinforcing fibers in the load-bearing part are filled with the polymer of the matrix. The matrix of the load-bearing part is most preferably hard in its material properties. A hard matrix helps to support the reinforcing fibers, especially when the rope bends. When bending, tension is exerted on the reinforcing fibers on the side of the outer surface of the bent rope and compression on the carbon fibers, in the longitudinal direction of them, on the side of the inner surface. The compression endeavors to crumple the reinforcing fibers. When a hard material is selected as the polymer matrix, the crumpling of fibers can be prevented because the hard material is able to support the fibers and thus to prevent their crumpling and to equalize the tensions inside the rope. To reduce the bending radius of the rope, among other things, it is thus preferred that the polymer matrix is of a polymer that is hard, preferably something other than an elastomer (an example of an elastomer: rubber) or something else that behaves elastically or gives way. Preferred materials are epoxy, polyester, phenolic plastic and vinyl ester. The polymer matrix is preferably so hard that its module of
elasticity \((E)\) is over 2 GPa, most preferably over 2.5 GPa. In this case the modulus of elasticity \((E)\) is preferably in the range 2.5-10 GPa, most preferably in the range 2.5-3.5 GPa.

In the method according to the invention for monitoring the condition of a rope and/or of roping, which rope 10,20,30,40,50 and/or roping \(R\) comprises a plurality of load-bearing parts, some \((T_{2,T_2',T_2''},T_2'''\)) preferably one, of which is/are arranged to be more susceptible to breakage in relation to the number of bends than the other load-bearing parts \((T_{1,T_1',T_1''},T_1'''\)), and that in the method the condition of the load-bearing part that is most susceptible to breakage \((T_{2,T_2',T_2''},T_2'''\)) is monitored. The rope and/or roping is according to what is presented elsewhere in this patent application, e.g. in Figs. 1-5. In the method the condition of the whole rope and/or of the whole roping is monitored by monitoring the condition of a part or parts that are susceptible to breakage, and if it is detected that a part that is susceptible to breakage has broken or the condition of it has fallen to below a certain predefined level, a need to replace or overhaul the rope or ropes is diagnosed and rope replacement work or rope maintenance work is started.

Fig. 7 presents one embodiment of an elevator according to the invention, in which the hoisting roping of the elevator is according to what is presented elsewhere in this patent application (e.g. according to what is defined in the description of any of Figs. 1-4) . The roping 10,20,30,40,50, \(R\) is fixed at its first end to the elevator car 3 and at its second end to the counterweight 6. The roping is moved with a traction sheave 2 supported on the building, to which traction sheave a power source, such as e.g. an electric motor (not shown), that rotates the traction sheave is connected. The rope is preferably of the
type presented in Figs. Ia-II in terms of its structure. The elevator is preferably a passenger elevator, which is installed to move in an elevator hoistway in a building. The elevator according to the invention preferably comprises a separate condition monitoring arrangement, which can comprise a condition monitoring apparatus connected to the part of the rope that is susceptible to breakage, which apparatus comprises means, such as e.g. a voltage source or current source, for transmitting an excitation signal along the part that is susceptible to breakage and means for detecting the response signal to the transmitted signal at a second point of the load-bearing part. These means can comprise e.g. a sensor and a processor, which when they detect a change in an electrical property raise an alarm about excessive wear of the rope. The condition monitoring apparatus can be e.g. connected to, for instance, both ends of the part that is susceptible to breakage such that the part susceptible to breakage forms a part of a circuit. On the basis of the response signal, preferably by comparing with the help of a processor to predetermined limit values, the condition monitoring apparatus can be arranged to deduce the condition of the load-bearing part in the area between the input point of the excitation signal and the measuring point of the response signal. The condition monitoring apparatus can be arranged to initiate an alarm if the response signal does not fall within the desired value range. The response signal changes when an electrical property that depends on the condition of a load-bearing part of the rope, such as resistance or capacitance, changes. For example, increasing resistance owing to breaks changes the response signal, from which change it can be deduced that the load-bearing part is in bad condition. The electrical property to be observed can be e.g. a change in the electric current or the resistance passing via the aforementioned circuit or a change in the magnetic field or a change in voltage.
It is obvious to the person skilled in the art that the invention is not limited to the embodiments described above, in which the invention is described using examples, but that many adaptations and different embodiments of the invention are possible within the frameworks of the inventive concept defined by the claims presented below. Thus it is obvious that toothings or other type of patterning can be formed on the surface of the ropes presented for producing a positive contact with the traction sheave. It is also obvious that the rectangularly-shaped composite parts presented in the figures can comprise edges with more pronounced roundings than those presented or with no roundings at all. It is also obvious that the matrix polymer, in which the reinforcing fibers are distributed, can comprise additives such as e.g. reinforcing, fillers, colors, fire retardants, stabilizers or corresponding agents, mixed into the basic polymer of the matrix, thus such as e.g. into the epoxy. It is also obvious that although the polymer matrix is preferably not of an elastomer, the invention can also be utilized with an elastomer matrix.

The neutral axis N in the width direction of the rope is preferably straight, in the manner presented in the figures, but in some cases it can be slightly curved, particularly if the rope passes around a cambered diverting pulley.

It is obvious that the invention can also be utilized in ropes, in which there is some other material instead of composite, such as e.g. metal. It is also obvious that the number of load-bearing parts of the ropes presented can be greater or smaller than what is presented. Correspondingly, the number of the parts that are susceptible to breakage can differ to what is presented, in which case more than
one that is susceptible to breakage can be inspected in order to determine the condition of the rope, although it is most advantageous to inspect the condition of only one part that is susceptible to breakage.
CLAIMS

1. Rope of a hoisting apparatus, more particularly of a passenger elevator, which rope comprises a plurality of parts (T1, T1', T1'', T1''', T2, T2', T2'', T2''''), which continue unbroken for essentially the whole length of the rope, which parts are preferably load-bearing parts, characterized in that at least one (T2, T2', T2'', T2''', T2'''') of the aforementioned parts (T1, T1', T1'', T1''', T2, T2', T2'', T2'''', T2'''') is arranged to be essentially more susceptible to breakage in relation to the number of bends than the other (T1, T1', T1'', T1''', T1''''') aforementioned parts.

2. Rope according to any of the preceding claims, characterized in that at least one (T2, T2', T2'', T2''', T2'''') of the aforementioned parts (T1, T1', T1'', T1''', T2, T2', T2'', T2'''', T2'''') is arranged to be essentially more susceptible to breakage in relation to the number of bends than the other (T1, T1', T1'', T1''', T1''''') aforementioned parts by arranging it to be more susceptible to breakage in its cross-sectional shape and dimensions than the other (T1, T1', T1'', T1''', T1'''') aforementioned parts, and in that the part that is susceptible to breakage and the others of the aforementioned parts are preferably of the same material.

3. Rope according to any of the preceding claims, characterized in that the rope comprises a plurality of load-bearing parts (T1, T1', T1'', T2, T2') in the longitudinal direction of the rope, which are distributed in the rope at a distance from each other in the width direction of the rope, and which rope can be bent around the neutral axis (N) of the width.
direction of the rope, and in that the rope comprises
at least one load-bearing part \((T_1, T_1', T_1'')\) that
extends in the thickness direction of the rope to a
first distance \((S_1, S_1', S_1''')\) from the neutral axis
\((N)\) of the width direction of the rope and at least
one load-bearing part \((T_2, T_2', T_2''')\) that extends to a
second distance \((S_2, S_2', S_2''''\)\) from the neutral axis
\((N)\) of the width direction of the rope, which second
distance is greater than the first distance \((S_1, S_1')\).

4. Rope according to any of the preceding claims,
characterized in that the width \((W)\) of the rope is
greater than the thickness \((T)\) of the rope.

5. Rope according to any of the preceding claims,
characterized in that the part that is susceptible to
breakage \((T_2, T_2', T_2'', T_2''', T_2''''\)\) is a load-bearing
part.

6. Rope according to any of the preceding claims,
characterized in that the tensile strengths and/or
the moduluses of elasticity of the part
\((T_2, T_2', T_2'', T_2''', T_2''''\)\) that is susceptible to breakage
and of at least some, preferably all, of the other
load-bearing parts \((T_1, T_1', T_1'', T_1''')\) are
dimensioned to be essentially the same.

7. Rope according to any of the preceding claims,
characterized in that the cross-sectional surface
areas of the part \((T_2, T_2', T_2'', T_2''', T_2''''\)\) that is
susceptible to breakage and of at least some,
preferably all, of the other load-bearing parts
\((T_1, T_1', T_1'', T_1''', T_1''''\)\) are essentially the same.

8. Rope according to any of the preceding claims,
characterized in that the width of the part that is
susceptible to breakage is smaller and the thickness of the part that is susceptible to breakage is greater than at least one of the other load-bearing parts of the rope.

9. Rope according to any of the preceding claims, characterized in that at least the part that is susceptible to breakage is visible outside the rope, preferably owing to the transparency of the coating binding the load-bearing parts to each other.

10. Rope according to any of the preceding claims, characterized in that at least one (T2'') of the aforementioned parts (T1'', T2'') is arranged to be essentially more susceptible to breakage in relation to the number of bends than the other parts (T1'') by manufacturing the part that is susceptible to breakage from a material that withstands bending worse than the material from which the other parts (T1'') are manufactured or by arranging an initial defect in the part that is susceptible to breakage, such as e.g. a transverse groove.

11. Rope according to any of the preceding claims, characterized in that the load-bearing parts (T1,T2,T1',T2',T2'',T2''') are of essentially the same material, preferably of completely the same material.

12. Rope arrangement (R) of a hoisting apparatus, more particularly of a passenger elevator, which comprises a plurality of ropes (30, 31), which are arranged to move the elevator car (3) e.g. by means of a traction sheave (2), characterized in that at least one (30) of the aforementioned ropes (30,31) is arranged to be essentially more susceptible to breakage in relation to the number of bends than the other ropes (31).
13. Rope arrangement (R) according to any of the preceding claims, characterized in that one (30) of the aforementioned ropes (30, 31) is arranged to be essentially more susceptible to breakage in relation to the number of bends than the other (31) aforementioned ropes by arranging it to be more susceptible to breakage in terms of the cross-sectional shape and cross-sectional dimensions of the load-bearing part than the other (31) aforementioned ropes (30,31), and in that the load-bearing parts of the rope that is susceptible to breakage and the other (31) load-bearing parts of the aforementioned ropes (30,31) are preferably of the same material.

14. Rope arrangement (R) according to any of the preceding claims, in which the aforementioned plurality comprises a plurality of ropes (30,31), of which each rope can be bent around the neutral axis (N) of the width direction of the rope, characterized in that the rope (30) that is susceptible to breakage comprises at least one load-bearing part (T2"/) that extends in the thickness direction of the rope to a second distance (S2") from the neutral axis (N) of the width direction of the rope, and in that the load-bearing parts (T1") of the other ropes (31) extend at most in the thickness direction of the rope to a first distance (S1) from the neutral axis (N) of the width direction of the rope, which first distance is smaller than the second distance.

15. Rope or rope arrangement according to any of the preceding claims, characterized in that the aforementioned load-bearing parts (T1, T1', T1'', T1''' , T2, T2', T2'', T2''' ) are of composite material, which composite material
comprises reinforcing fibers, which are preferably of carbon fiber or glass fiber, embedded into a polymer matrix.

16. Rope or rope arrangement according to any of the preceding claims, characterized in that the aforementioned reinforcing fibers (F) are essentially electrically conductive.

17. Rope or rope arrangement according to any of the preceding claims, characterized in that the aforementioned reinforcing fibers (F) are of non-metallic, preferably synthetic fibers.

18. Rope or rope arrangement according to any of the preceding claims, characterized in that the density of the aforementioned reinforcing fibers (F) is less than 4000kg/m³, and the strength is over 1500 N/mm², more preferably so that the density of the aforementioned fibers (F) is less than 4000kg/m³, and the strength is over 2500 N/mm², most preferably so that the density of the aforementioned fibers (F) is less than 3000kg/m³, and the strength is over 3000 N/mm².

19. Rope or rope arrangement according to any of the preceding claims, characterized in that the load-bearing part (T₁, T₁', T₁'', T₁''', T₂, T₂', T₂'', T₂''') is a solid elongated rod-like piece.

20. Rope or rope arrangement according to any of the preceding claims, characterized in that each aforementioned load-bearing part (T₁, T₁', T₁'', T₁''', T₂, T₂', T₂'', T₂''') is
parallel with the longitudinal direction of the rope (10,20,30,40,50).

21. Rope or rope arrangement according to any of the preceding claims, characterized in that the structure of each aforementioned rope (10,20,30,31,40,50) continues essentially the same for the whole distance of the rope (10,20,30,31,40,50).

22. Elevator, preferably a passenger elevator, which comprises an elevator car (3), a traction sheave (2), a power source for rotating the traction sheave (2), characterized in that it comprises a rope according to any of claims 1-10 and/or a rope arrangement (R) according to any of claims 11-17, and in that the elevator car (3) is arranged to be moved by means of the aforementioned rope (10,20,30,40,50) and/or rope arrangement (R).

23. Elevator according to any of the preceding claims, characterized in that the rope (10,20,30,40,50) and/or rope arrangement (R) is arranged to move an elevator car (3) and a counterweight (6).

24. Elevator according to any of the preceding claims, characterized in that the elevator comprises means for monitoring the condition of the part of the rope (T2,T2', T2'', T2''', T2'''') that is susceptible to breakage, which means monitor preferably only some of the load-bearing parts (T1,T1', T1'', T1''', T2, T2', T2'', T2''', T2'''') of the rope, preferably only the condition of the aforementioned part of the rope that is susceptible to breakage.
25. Method for monitoring the condition of a rope and/or roping, which rope and/or roping comprises a plurality of load-bearing parts, characterized in that some (T₁, T₁', T₁'', T₁''', T₂, T₂', T₂'', T₂'''', T₂''''', T₂''''''') preferably one, of the load-bearing parts is/are arranged to be more susceptible to breakage in relation to the number of bends than the other load-bearing parts (T₁, T₁', T₁'', T₁''', T₁'''''), and in that in the method the condition of the load-bearing part that is most susceptible to breakage (T₂, T₂', T₂'', T₂''', T₂'''', T₂''''') is monitored.

26. Method according to any of the preceding claims, characterized in that the rope and/or roping is according to any of the preceding claims.

27. Method according to any of the preceding claims, characterized in that in the method the condition of all the aforementioned load-bearing parts (T₂, T₂', T₂'', T₂''', T₂''''') is not monitored.

28. Method according to any of the preceding claims, characterized in that in the method the condition of the rope (10, 20, 30, 40, 50) and/or roping (R) is monitored by monitoring the condition of a part (T₂, T₂', T₂'', T₂''', T₂''''') or parts that are susceptible to breakage, and if it is detected that a part that is susceptible to breakage has broken or the condition of it has fallen to below a certain predefined level, a need to replace or overhaul the rope or ropes is diagnosed and rope replacement work or rope maintenance work is started.
Method according to any of the preceding claims, characterized in that in the method the condition of the rope (10, 20, 30, 40, 50) and/or of the roping (R) is monitored by monitoring changes in an electrical property of the part (T₂, T₂', T₂'', T₂''', T₂''''') or the parts that are susceptible to breakage.

Rope, rope arrangement, elevator or method according to any of the preceding claims, characterized in that the tension produced by the weight of the elevator car/counterweight is transmitted along at least one (T₂, T₂', T₂'', T₂''', T₂''''') of the aforementioned parts (T₁, T₁', T₁'', T₁''', T₂, T₂', T₂'', T₂''', T₂'''') from the elevator car/counterweight at least to the traction sheave (2).

Rope, rope arrangement, elevator or method according to any of the preceding claims, characterized in that at least one (T₂, T₂', T₂'', T₂''', T₂''''') of the aforementioned parts (T₁, T₁', T₁'', T₁''', T₂, T₂', T₂'', T₂''', T₂'''') is arranged to be essentially more susceptible to breakage in relation to the number of bends than the other (T₁, T₁', T₁'', T₁''', T₁''''') aforementioned parts by arranging it to be more susceptible to breakage in its cross-sectional shape and dimensions than the other (T₁, T₁', T₁'', T₁''', T₁''''') aforementioned parts, and in that the part that is susceptible to breakage and the others of the aforementioned parts are of the same material.