

System for anchoring a cable

TECHNICAL FIELD

The invention relates to a cable anchoring system, a lifting device comprising such an
5 anchoring system and a lift machine comprising said anchoring system.

PRIOR ART

The lifting and handling of containers can be implemented using a spreader, connected
10 by way of ropes to a crane of "Ship to Shore" (STS) type, for disembarking containers from a ship or embarking containers onto a ship. Motors mounted on the crane are used to lift or lower the spreader by way of the ropes. Fastening members (commonly known as "twist locks") are moreover attached to the spreader. The opening – or closing, respectively – of the fastening members makes it possible to attach – or release, respectively – a container. To enable their
15 opening or closing, the fastening members are usually powered by a hydraulic unit, most commonly arranged on the spreader. The hydraulic unit can moreover be adapted to force the extension or retraction of the spreader during use, so as to adapt said spreader to the lifting of containers of different sizes. The hydraulic unit is advantageously powered from the crane by way of a cable: a first end of the cable is wound around a winder mounted on the crane and a
20 second end of the cable is connected to the spreader, advantageously by way of a frame (commonly known as a "head block") under which said spreader is mounted. Alternatively, the fastening members are entirely electrical, and their supply of power from the crane is also provided via such a cable. The cable may further comprise a databus, for example a CAN (Controller Area Network) bus, in charge of transmitting the locking or unlocking information to
25 the fastening members along with any other item of information needed to control the crane (weighing, lighting etc.).

To avoid damaging the cable, the unwinding and winding of the cable around the winder must make it possible to keep the cable taut during all the operations of lifting, unloading,
30 loading etc. of the containers. The unwinding and winding of the cable around the winder, so as to follow the movement of the spreader, are usually handled automatically by slaving the winder according to a theoretical model which computes the torque to be applied to the winder according to the operating phase and the position of the crane on its track.

35 However, since the motion of the spreader is often managed manually by the crane operator, certain movements of the spreader cannot be immediately compensated for by the winder. This is especially true in the event of sudden movements of the spreader when said

frame is subject to impacts, for example if the container misses the hatch and strikes the guides of the container ship.

5 A cable anchoring system is consequently mounted on the frame under which the spreader is mounted. This anchoring system may comprise a cylindrical drum advantageously mounted rotatably with respect to the frame by way of bearings, for example ball bearings. Under the effect of the cable tension, for example in the event of a sudden movement of the spreader, said drum is set to rotate about its axis of rotation. The rotational movement of the drum incurs the winding and/or unwinding of the cable around said drum, thus allowing the
10 cable a certain amount of travel.

The anchoring system may further comprise a compression spring coupled to one or more dampers, for example hydraulic, metallic or elastic (tensioner) dampers, suitable for damping the cable travel. More specifically, when the winder pulls or pushes on the cable and
15 the drum is set in rotation, the compression spring supplies a return force on said drum proportional to the elongation of said compression spring under the effect of the rotation of the drum and the damper absorbs the impact.

However, such anchoring systems, the bulk of which is limited by the size of the frame
20 on which they are housed, do not permit sufficient travel of the cable, particularly in the event of impacts. Specifically, the travel allowed to the cable by the anchoring system is typically in the order of 40 mm in the direction of unwinding of the cable when the winder pulls on the cable and of 40 mm in the direction of winding of the cable when the winder releases the tension on the cable. This results in rapid wear of the cable, which requires frequent, expensive
25 maintenance operations.

Furthermore, the compression spring is subject to high stresses and consequently has a short lifetime which can be less than one year of use of said spring at a rate of approximately 2000 hours of use of the spring per year. It is then necessary to change the anchoring system
30 or to replace the spring. The lifetime of the bearings is also shorter than is desirable.

Moreover, the compression spring and/or other damping means that the anchoring system may comprise can prove bulky.

35 **BRIEF DESCRIPTION OF THE INVENTION**

An aim of the invention is to design a cable anchoring system, preferably suitable for being mounted on a frame of a crane intended to support a spreader, making it possible to

allow the cable a larger amount of travel than the previously described anchoring systems and which remains of small bulk and easy to manufacture.

For this purpose, the invention makes provision for a cable anchoring system comprising:

- a frame,
- 5 - a drum mounted rotatably on the frame about an axis of rotation, the drum having a lateral surface around an axis parallel to the axis of rotation, the drum being suitable for allowing travel of the cable by the winding and/or unwinding of said cable along a portion of the lateral surface, by the rotation of said drum about the axis of rotation in response to a variation in the tension of the cable.
- 10 - at least one torsion spring arranged between the drum and the frame so as to compensate for the variation in the tension of the cable.

Under the effect of the movement of rotation of the drum about the axis of rotation, the torsion spring generates an angle of torsion about said axis of rotation to compensate for the variation in the tension of the cable. Contrariwise, a compression spring generates an elongation, and to be capable of compensating for the variation in the tension of the cable, 15 said compression spring must be supplemented with yokes and/or pivot couplings. Furthermore, torsion springs are of small bulk and increasing the travel allowed to the cable by the winding and/or unwinding of said cable around the lateral surface equates to increasing the angular offset between the end angles of torsion of said torsion spring, which incurs little or no additional bulk, or difficulties in manufacturing said torsion springs. Contrariwise, 20 increasing the travel allowed to the cable with a compression spring equates to increasing the length of said compression spring, and therefore its bulk, and/or bringing said compression spring closer to said axis of rotation, which means that said compression spring must be capable of withstanding much larger forces. Such a compression spring is difficult to manufacture. The anchoring system comprising said torsion spring(s) is therefore easier to 25 manufacture, more adaptable and less bulky.

According to other optional but advantageous features considered alone or in combination:

- the at least one torsion spring comprises a first part mounted on the frame and a 30 second part mounted on the drum, the second part being suitable for pivoting with respect to the first part;
- the cable anchoring system comprises at least two torsion springs disposed in series;
- a first part of a first spring is mounted on the frame, a first part of a second spring 35 is mounted on the drum, and a second part of the first spring is rigidly connected to a second part of the second spring;

- each torsion spring comprises a rigid and hollow outer shaft, a rigid central shaft housed inside the rigid and hollow outer shaft, and a damper configured to damp a torsional movement of the rigid and hollow outer shaft in relation to the rigid central shaft;

- the damper of the torsion spring comprises a plurality of elastomer elements arranged between the rigid central shaft and the rigid and hollow outer shaft;

- each torsion spring comprises a first metallic and hollow square-based prism forming the rigid and hollow outer shaft, a second prism forming the central shaft arranged in the first prism with an angular offset with respect to the first prism, and each elastomer element is a cylinder arranged between the first prism and the second prism, in each corner of the first prism;

- the anchoring system comprises two torsion springs in series, the second square-based prism of the first torsion spring being connected to the second square-based prism of the second torsion spring;

- the at least one torsion spring is configured to damp the forces generated by the rotation of the drum about the axis of rotation between a first stop position of the drum and a second stop position of the drum, the first stop position and the second stop position being angularly offset with respect to the axis of rotation by an angle between 0° and 90° , preferably between 0° and 60° .

- the anchoring system comprises at least two sets of torsion springs disposed in parallel, a first part of each set of torsion springs being mounted on the frame and a second part of each set of torsion springs being mounted on the drum;

- the anchoring system further comprises a compression spring and/or a tension spring comprising a first part mounted on the frame and a second part mounted on the drum.

Another subject of the invention relates to a lifting device comprising:

- a spreader comprising at least one fastening member for fastening a load to be lifted,
- a cable anchoring system as previously described comprising a frame and a drum, the frame being attached to the spreader and the drum being attached to the frame,

- a winder suitable for being attached to a lift machine,

- a cable, a first end of the cable being anchored to the drum of the anchoring system by a fixed winding of at least two turns around the lateral surface of the drum and a second end of the cable being wound around the winder.

Another subject of the invention relates to a lift machine, such as a crane, a gantry or a forklift truck, comprising a lifting device as previously described.

BRIEF DESCRIPTION OF THE FIGURES

Other features and advantages of the invention will become apparent from the following detailed description, with reference to the appended drawings, wherein:

- figures 1A, 1B and 1C illustrate an example of an application of a cable anchoring system according to the invention in which said system is attached to a spreader itself mounted on a crane;

- figures 2A, 2B and 2C show a particular embodiment of the cable anchoring system according to the invention in which the lateral surface of the drum has a circle shape and an axis of rotation of the drum relative to the frame passing through the center of the circle: figure 2A shows the neutral position of the drum, figure 2B shows the scenario of the application by the cable of an under-tension on the drum driving the rotation of said drum in the direction of winding of the cable, figure 2C shows the scenario of the application by the cable of an over-tension on the drum driving the rotation of said drum in the direction of unwinding of the cable;

- figures 3A, 3B and 3C show a particular embodiment of the cable anchoring system according to the invention in which the lateral surface of the drum has a circle shape and an axis of rotation of the drum relative to the frame offset with respect to the center of the circle: figure 3A shows the neutral position of the drum, figure 3B shows the scenario of the application by the cable of an under-tension on the drum driving the rotation of said drum in the direction of winding of the cable, figure 3C shows the scenario of the application by the cable of an over-tension on the drum driving the rotation of said drum in the direction of unwinding of the cable;

- figures 4A, 4B and 4C show a particular embodiment of the cable anchoring system according to the invention in which the lateral surface of the drum has an ellipse shape and an axis of rotation of the drum relative to the frame offset with respect to the center of the ellipse: figure 4A shows the neutral position of the drum, figure 4B shows the scenario of the application by the cable of an under-tension on the drum driving the rotation of said drum in the direction of winding of the cable, figure 4C shows the scenario of the application by the cable of an over-tension on the drum driving the rotation of said drum in the direction of unwinding of the cable;

- figure 5 shows a cable anchoring system in which said system comprises a drum having an elliptical shape and an axis of rotation offset with respect to the center of the ellipse along with a compression spring suitable for damping the travel of the cable by winding and/or unwinding the cable around a portion of the ellipse;

- figure 6 shows a particular embodiment of a torsion spring comprising a first metallic and hollow square-based prism, a second metallic and hollow square-based prism housed inside the first prism with an angular offset with respect to the first prism, and four elastomer cylinders arranged between the first prism and the second prism in the corners of the first prism;

- figures 7A, 7B, 7C and 7D show a particular embodiment of the anchoring system of the invention in which said system comprises a drum having an elliptical shape and an axis of rotation offset with respect to the center of the ellipse along with two sets of torsion springs suitable for damping a travel of the cable by the winding and/or unwinding of the cable around a portion of the ellipse and arranged along the axis of rotation of the drum so as to allow the rotation of said drum relative to the frame, each set of torsion springs comprising two torsion springs mounted in series, figure 7B showing the neutral position of the drum, figure 7C showing the scenario of the application by the cable of an under-tension on the drum driving the rotation of said drum in the direction of winding of the cable, figure 7D showing the scenario of the application by the cable of an over-tension on the drum driving the rotation of said drum in the direction of unwinding of the cable;

- figure 8 shows a particular embodiment of the anchoring system according to the invention in which at least one torsion spring is a metallic spring, the anchoring system further comprising a shaft and a bearing, the shaft and the bearing being configured to guide the rotation of the drum relative to the frame about its axis of rotation.

For reasons of legibility, the drawings are not necessarily to scale.

DETAILED DESCRIPTION OF EMBODIMENTS

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The invention relates to a cable anchoring system comprising a frame and a drum, the drum being suitable for being mounted on the frame and for anchoring the cable to said frame.

With reference to figures 1A, 1B and 1C, the frame 2 is preferably a frame suitable for being mounted on a spreader 4, said spreader 4 comprising one or more fastening members 5, said fastening members being suitable for picking up a load. The fastening members 5 of the spreader 4 may for example comprise four twist locks suitable for gripping a container. When it is in use, the spreader 4 is connected to a lift machine 6, for example a crane, by lifting means 7 of said spreader 4, said lifting means 7 being suitable for allowing the movement of the spreader 4 in relation to the lift machine 6, typically the ascent or descent of said spreader 4, said movement being able to be remotely controlled by an operator, for example a crane driver positioned in the driver's cabin or in a driving room from which he controls several cranes alternately. Alternatively, said movement can be managed completely automatically without the involvement of said operator. The lifting means 7 of the spreader 4 may comprise ropes and one or more motors mounted on the lift machine 6.

According to an embodiment not shown on figures 1A, 1B and 1C, a second spreader can be connected to the lift machine 6 by lifting means of said second spreader, said lift

machine 6 further comprising an intermediate platform. Such a configuration is particularly advantageous when the lift machine is an STS crane: the spreader 4 is used to move a container between the ship and the platform while the second spreader is used to move said container between the platform and the dock.

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The cable 3 comprises one or more conductive links for power and/or data transfer. Each conductive link can take the form of an electrically conductive wire, an optical fiber, or any other appropriate form. Preferably, the cable comprises at least a conductive link for supplying power and a conductive link for controlling the fastening members 5 of the spreader 4. When
 10 the drum 1 is in use, i.e. when the drum 1 is mounted on the frame 2, the frame 2 mounted on a spreader 4 and the spreader 4 connected to a lift machine 6, a first end of the cable is anchored to the frame 2 by way of the drum 1 and a second end of the cable 3 is wound around a winder mounted on the lift machine 6. More precisely, the drum according to the invention comprises a lateral surface (S) located around an axis (Y), such that when the drum 1 is in
 15 use, the first end of the cable 3 is wound around said lateral surface (S).

The winder mounted on the lift machine is typically an electronically-controlled winder comprising a motor which winds or unwinds the cable so as to keep the cable taut whatever the operating phase of the spreader (for example in ascent, descent, setting in motion or
 20 stopping). A control unit computes a torque setpoint to be applied according to said operating phase. The value of the torque must be high enough to keep the cable taut without damaging the cable. The torque setpoint is sent to a frequency variator which translates said torque setpoint into a current to be imposed on the motor. A variation in the torque setpoint, for
 25 example when the position of the spreader changes or the operating phase changes, causes a variation in the motor current. Such a control loop has a non-zero reaction time which is the sum of at least a reaction time related to the electronics and a reaction time related to the conversion of the current setpoint. The reaction time related to the electronics is estimated as being in the order of 75 ms. This reaction time does not allow the winder to respond quickly
 30 enough in certain situations, for example in the event of sudden movements of the spreader, or for example in the event of impacts or gusts of wind, thus generating tension in the cable.

The drum 1 is therefore suitable for being mounted rotatably on the frame 2 about an axis of rotation (X) parallel to the axis (Y), so that when the drum 1 is in use, the drum 1 can be freely rotated about the axis of rotation (X) under the effect of a tension in the cable 3 not
 35 immediately compensated for by the winder, thus allowing the travel of the cable 3 by the winding and/or unwinding of said cable around the lateral surface (S) along a portion of the lateral surface (S).

More precisely, the drum, in a position described as neutral, can be subjected to a tensile force from the cable due to the torque imposed on said cable by the winder, making it possible to keep said cable taut. A mechanical tension of the cable is understood to mean a variation of the tensile force applied by the cable to the drum in relation to the tensile force applied to said drum in the neutral position. It can be an under-tensile force (configuration corresponding to cable slack) or an over-tensile force (configuration in which the winder pulls on the cable with a higher amount of tensile force than the theoretical value resulting from the setpoint). Such a mechanical tension will cause a rotational movement of the drum about the axis of rotation (X) with respect to this neutral position. In the under-tensile force case, the rotational movement about the axis of rotation (X) will be done in the direction of winding to pick up the cable slack until, optionally, a first stop position is reached. In the over-tensile force case, the rotational movement about the axis of rotation (X) will take place in the direction of unwinding of the cable to release the cable until, optionally, a second stop position is reached.

By way of example, the first and the second stop position are angularly offset with respect to the axis of rotation (X) by an angle between 0° and 60° , preferably an angle between 0° and 90° .

The lateral surface (S) of the drum in a plane (P) perpendicular to the axis of rotation (X) can have a circle shape. Alternatively, the lateral surface (S) can have, in the plane (P), an ovoid or ellipse shape, or any other shape whose the bend radius is not constant.

The axis of rotation (X) can intersect with the plane (P) at the center of the circle of radius equal to the bend radius of the portion of the lateral surface along which the cable is wound and/or unwound and tangent to said portion. For example, if the lateral surface has, in the plane (P), a circle shape, the axis of rotation (X) can intersect with the plane (P) at the center of the lateral surface.

Alternatively, the axis of rotation (X) can intersect with the plane (P) at any other point of the plane (P).

Figures 2A, 2B and 2C show a particular example of a drum in use on a frame, in which said drum has a circle shape in the plane (P) and the axis of rotation (X) intersects with the plane (P) at the center of the circle. In particular, figure 2A shows the configuration in which the drum is in a neutral position. Figure 2B shows the scenario of an under-tension of the cable: the drum turns from said neutral position in the direction of winding of said cable about the axis of rotation (X) to wind up the cable slack. Figure 2C shows the scenario of an over-tension of

the cable; the drum turns from the neutral position in the direction of unwinding of the cable around the axis of rotation (X) to unwind cable.

Figures 3A, 3B and 3C show another particular example of a drum in use on a frame, in which said drum still has a circle shape in the plane (P) but the axis of rotation (X) does not intersect with the plane (P) at the center of the circle. In particular, figure 3A shows the configuration wherein the drum is in the neutral position. Figure 3B shows the scenario of under-tension of the cable. Figure 3C shows the scenario of over-tension of the cable.

Still by way of example, figures 4A, 4B and 4C show a case in which said drum has an ellipse shape in the plane (P) and the axis of rotation (X) intersects with the plane (P) not at the center of the ellipse, but at the center of the circle of radius equal to the bend radius of the portion of the lateral surface (S) of winding and/or unwinding of the cable and tangent to said portion. Figure 4A shows the neutral position of the drum, figure 4B the scenario of under-tension of the cable and figure 4C the scenario of over-tension of the cable.

Preferably, the drum is arranged so that during the use of said drum, a first part of the first end of the cable remains wound around said surface (S) in all the phases of use of the frame, and a second part of said cable in the extension of the first part winds and/or unwinds along the portion of the lateral surface (S) due to the rotational movement of the drum about the axis of rotation (X) between the first and second stop position. By way of example, the first part of the first end of the cable has a length at least equal to two full turns of the surface (S), preferably greater than two and a half turns. The first part of the first end is advantageously long enough to cancel out the tensioning of the cable at the end of said cable by a so-called capstan effect. In a manner known *per se*, the capstan effect establishes the ratio between a retaining force applied to one end of a cable wound around the lateral surface of a cone, for example a cone of a circular section or a cone of non-circular section (for example an elliptical section), and a load force applied to an opposite end of said cable which depends on the frictional coefficient of the cable on the lateral surface of the cone.

The anchoring system according to the invention further comprises at least one torsion spring arranged between the drum and the frame. When a sudden tension of the cable on the drum drives the rotation of the drum about said axis of rotation (X) in the direction of winding or unwinding of the cable (where the sudden tension of the cable is understood to mean a variation in the mechanical tension in relation to the equilibrium tension that makes it possible to keep the cable taut), the torsion spring is configured to generate a return force on said drum which tends to compensate for said variation in tension. Thus, by way of the drum, the torsion spring makes it possible to limit the tensions in the cable and keep the cable taut, and thus

avoid damaging the cable. Preferably, the torsion spring or the set of torsion springs generates all the return forces on the drum. Alternatively, the anchoring system may further comprise a compression spring and/or a tension spring, such that said compression spring and/or said tension spring generate at least a part of the return forces on the drum.

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More precisely, under the effect of the mechanical tension of the cable and the resulting rotation of the drum about the axis of rotation (X), each torsion spring deforms, generating an angle of torsion and therefore a return force on the drum proportional to said angle of torsion which tends to cancel out said angle of torsion and bring the drum back into its initial position.

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In the direction of winding of the cable, the torsion spring can deform until it reaches a first limit angle of torsion. In the direction of unwinding of the cable, the torsion spring can deform until it reaches a second limit angle of torsion. In a variant, the first limit angle of torsion and the second limit angle of torsion respectively correspond to a first stop position and to a second stop position of the drum in rotation about the axis of rotation (X). In other words, the rotation

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of the drum about the axis of rotation (X) is locked in one direction by the torsion spring when the torsion spring has reached the first limit angle of torsion and the rotation of the drum is locked in the other direction when the torsion spring has reached the second limit angle of torsion. In a preferred variant, the first stop position and the second stop position are reached by the drum in rotation about the axis of rotation (X) slightly before the torsion spring reaches its first limit angle of torsion and its second limit angle of torsion. Such a form of execution advantageously makes it possible to avoid wearing out the torsion spring too quickly. In practice, the first stop position and the second stop position can be fixed by external mechanical stops, for example progressive rubber stops, well-known to those skilled in the art, which will damp the impact when the drum reaches its stop position. Typically, the first – or respectively second – stop position and the first – or respectively second – limit angle of torsion are angularly offset by approximately 4° .

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The arrangement of the torsion spring(s) between the drum and the frame can be embodied such that each torsion spring is in the middle of its deformation range when the drum is in the neutral position. This makes it possible to obtain an equivalent amount of travel in the direction of winding of the cable and in the direction of unwinding of the cable.

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By way of example, if the first and the second stop position are angularly offset with respect to the axis of rotation (X) by an angle of 90° , the middle of the deformation range of each torsion spring is preferably associated with a position of the drum at 45° . Still by way of example, if the first and the second stop position are angularly offset with respect to the axis of rotation (X) by an angle of 60° , the middle of the deformation range of each torsion spring is preferably associated with a position of the drum at 30° .

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A torsion spring advantageously has a smaller bulk than the compression spring conventionally used (see Figure 5 with the compression spring 8 comprising a first part attached to the frame and a second part attached to the drum), in particular when the torsion spring is disposed along the axis of rotation (X). Specifically, a compression spring has a limited length of elongation or compression: increasing the travel allowed to the cable therefore requires either, at a fixed distance between the compression spring and the axis of rotation (X), an increase in the length of the compression spring and therefore the bulk of said spring, or the bringing of the spring closer to the axis of rotation (X). In the latter case, however, the compression spring must be capable of withstanding a very large force to counterbalance that of the cable. Specifically, the cable tension can be in the order of 2000 N along the axis of the cable and the tension on the spring, potentially greater still, is even stronger when the spring is placed close to the axis of rotation. To be capable of withstanding such a force, the compression spring must therefore have a greater wire thickness, which also substantially increases its length and thus its bulk, but also gives rise to concerns regarding the manufacturability of said compression spring.

Furthermore, the compression spring, like any spring, must preferably be used in its linear region without reaching its stop positions, in order to avoid excessively reducing the lifetime of said spring, which requires the length of said compression spring to be increased yet further.

By way of example, let us consider a conventional anchoring system comprising a compression spring of 240 mm of free length and 86 mm of elongation amplitude, in which the position of the compression spring is such that the compression spring must slightly pivot at each of its ends to follow the movement of the drum but in which the ratio of the travel of the spring to the travel of the cable remains approximately 1:1. Such a cable anchoring system therefore allows the cable a travel in the order of 86 mm. To increase the travel of the cable to 630 mm without altering the position of the compression spring, it would therefore be advisable to replace said compression spring of 240 mm in length with a compression spring of $(240 \times 630)/86$ mm, i.e. approximately 1.9 m.

Alternatively, if one wished to keep an actual spring length of 240 mm while allowing the cable a travel of 630 mm, said compression spring would have to be positioned approximately 7 to 8 times closer to the axis of rotation, which would greatly increase the forces undergone by said compression spring at the same proportions. In such a configuration, the compression spring would of necessity have a far greater wire diameter, and thus, in the end, a spring length probably longer than the desired 240 mm. A compression spring having such features is either

impossible or very difficult to manufacture. Furthermore, all the attachment parts of the compression spring subjected to these considerable forces would also have to be dimensioned to withstand said considerable forces, which would drastically increase the cost of the overall anchoring system. Finally, the risk of failure of such an anchoring system would be very high.

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The force undergone by the torsion spring directly generates an angle of rotation and increasing the travel allowed to the cable equates to increasing this angle of rotation, which has no effect on the bulk. Furthermore, the torsion spring can be easily disposed along the axis of rotation (X) inside the drum, which leads to a minimal bulk.

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As mentioned previously, the forces to which the compression spring or the at least one torsion spring on the anchoring system are subjected are considerable. To avoid the lifetime of a compression spring used under such conditions being too short, it is advisable to use said compression spring only in its operating range and to increase the diameter of the wire of said compression spring. Thus, a trade-off is imposed between the bulk of the compression spring and the lifetime of said compression spring. Contrariwise, the torsion spring of the anchoring system according to the invention works exactly under the conditions for which it was designed, namely alternating torsions, so that an anchoring system comprising such a torsion spring can reach longer lifetimes.

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More precisely, in a first embodiment, the anchoring system comprises a torsion spring arranged along the axis of rotation (X). A first part of said torsion spring is mounted on the frame and a second part of said torsion spring is mounted on the drum, the second part being suitable for pivoting with respect to the first part.

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Thus arranged, the first and the second stop position may correspond to the end positions of pivot of the second part of the torsion spring in relation to the first part. According to a preferred alternative, the first and the second stop position are contained between the end positions of pivot of the second spring part of the spring in relation to the first part (for example by means of external mechanical stops as previously mentioned). Not turning all the way to the end positions when the drum is in use advantageously avoids pointlessly reducing the lifetime of the torsion spring.

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In a second embodiment of the anchoring system according to the invention, the cable anchoring system comprises at least two torsion springs mounted in series and arranged along the axis of rotation (X). In the variant in which the anchoring system comprises two torsion springs mounted in series, a first part of a first torsion spring can be mounted on the frame, a first part of a second torsion spring can be mounted on the drum, and a second part of the first

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torsion spring can be rigidly connected to a second part of the second torsion spring, the first part of the first torsion spring – or of the second torsion spring respectively – being suitable for pivoting with respect to the second part of the first torsion spring – or of the second torsion spring respectively.

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For a given lateral surface (S), the arrangement of two torsion springs in series advantageously makes it possible to double the angle between the first and the second stop position with respect to the axis of rotation (X) and therefore to increase the length measured in the plane (P) of the portion of the lateral surface (S) along which the cable is wound and/or unwound. In other words, this makes it possible to increase the travel allowed to the cable. Thus, if the angle between the first and the second stop position with respect to the axis of rotation (X) with a torsion spring is between 0° and 30°, the series mounting of two torsion springs advantageously makes it possible to increase the angle between the first and the second stop position to an angle between 0° and 60°.

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In other variants, the anchoring system comprises at least three torsion springs mounted in series, so as to increase still further the angle between the first stop position and the second stop position, and therefore the travel allowed to the cable. However, in such variants, at least one of the series-mounted torsion springs – said median torsion spring – is not fitted either on the drum, or on the frame, so that the torsion springs and the connecting parts on either side of said median spring must bear said median torsion spring and withstand the forces generated by said median torsion spring. The variant with only two torsion springs in series is therefore the preferred variant.

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By way of example, an angle of travel between the first stop position and the second stop position of between 0° and 60° makes it possible to sweep a portion of a length between 0 and approximately 630 mm measured in the plane (P) when the bend radius of the portion of the lateral surface (S) measures 575 mm, the diameter of the cable measures 50 mm and the distance d' measured in the plane (P) between the cable and the straight line of the plane (P) parallel to said cable which intersects with the axis of rotation (X) is advantageously equal to the bend radius of said portion of the lateral surface (S). Specifically, the arc length of the portion of the cable l can be calculated as follows:

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$$l = \frac{2 \times (575 + 25) \times \pi \times 60}{360} = 628.32 \text{ mm} \cong 630 \text{ mm}$$

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Such a length makes it possible to allow the cable a travel in the order of 30 mm in the direction of winding of the cable and of 300 mm in the direction of unwinding of the cable. Such a travel is considered by the inventors as the ideal travel for the cable from the neutral position.

Specifically, the ideal travel making it possible to keep the cable taut so as to avoid damaging is equal to the product of the maximum speed of the spreader by the reaction time of the feedback loop of the electronically-controlled winder. The maximum linear speed given by the motors to the spreader being typically between 150 m/min or 2.5 m/s and 240 m/min or 4 m/s and the reaction time of the electronically-controlled winder being in the order of 75 ms, the ideal travel from the neutral position is therefore indeed in the order of 300 mm both in the direction of unwinding and of winding of the cable on the drum. The series arrangement of two or more torsion springs advantageously makes it possible to allow the cable such a travel while limiting the bulk. As previously mentioned, such a travel length is not reasonably achievable with a compression spring.

Each torsion spring may comprise a metallic spring arranged along the axis (X). For example and as shown on Figure 8, the cable anchoring system comprises a single metallic torsion spring 10, a first coil 11a of a first end of said metallic spring being rigidly connected to the frame 2 and a second coil 11b of a second end of said spring being rigidly connected to the drum 1. In this configuration, the anchoring system may further comprise a shaft 12 rigidly connected to the frame 2 and oriented along the axis of rotation (X), and a bearing (not shown) rigidly connected to the drum 1. In this way, the bearing and the shaft 12 provide the rotational guiding of the drum 1 in relation to the frame 2 along the axis of rotation (X). Alternatively, the shaft can be rigidly connected to the drum and the bearing rigidly connected to the frame. The shaft 12 is for example arranged inside the coils of the metallic torsion spring 10. Preferably, the anchoring system of figure 8 further comprises at least one damper (not shown), for example a hydraulic, pneumatic, metallic or elastic (tensioner) damper, which makes it possible to damp the impacts.

The first stop position and the second stop position of the drum can be respectively set by the first limit angle of torsion and the second limit angle of torsion of the metallic torsion spring 10 (permanent deformation of said spring). Alternatively, the diameter of the shaft 12 can be carefully chosen, such that the first stop position and the second stop position correspond to the angles of torsion of the torsion spring 10 at which said torsion spring is "locked" by the shaft 12. In a preferred variant, the cable anchoring system further comprises at least two mechanical stops which lock the rotation of the drum before the single metallic spring 10 reaches the first limit angle of torsion and the second limit angle of torsion. Each mechanical stop for example comprises a first part secured to the frame and a second part secured to the drum: when the drum rotates about the axis of rotation (X), the second part of the mechanical stop then locks against the first part of the mechanical stop, thus stopping the rotational movement of the drum in a stop position. Preferably, at least one mechanical stop is a progressive rubber stop, well-known to those skilled in the art.

Alternatively and advantageously, each torsion spring may comprise a rigid and hollow outer shaft, a rigid central shaft housed inside the rigid and hollow outer shaft, and a damper configured to damp a torsional movement of the rigid and hollow outer shaft in relation to the rigid central shaft. On the anchoring system, the rigid central shaft and the rigid and hollow outer shaft are oriented along the axis of rotation (X).

In the particular configuration in which the anchoring system comprises a single torsion spring comprising a rigid and hollow outer shaft, a rigid central shaft housed inside the rigid and hollow outer shaft, and a damper as previously described, the rigid central shaft can be mounted on the drum and the rigid and hollow outer shaft can be mounted on the frame, such that the torsion/pivoting of the rigid and hollow outer shaft in relation to the rigid central shaft about the axis of rotation (X) provides the rotational guiding of the drum relative to the frame along the same axis. In other words, in this configuration the torsion spring plays the dual role of bearing, to guide the rotational movement of the drum relative to the frame, and of damper of the forces generated by said movement. Alternatively, the rigid central shaft can be mounted on the frame and the rigid and hollow outer shaft can be mounted on the drum.

Such a torsion spring comprising a rigid central shaft housed inside a rigid and hollow outer shaft advantageously makes it possible to avoid using other means for rotatably mounting the drum relative to the frame such as roller bearings or pads (see Figure 5 on which roller bearings 9 are used in conjunction with the compression spring 8, the roller bearings 9 enabling the rotation of the drum about the axis of rotation (X) and the compression spring damping said movement). Indeed, said roller bearings or pads are not suitable for the conditions of use of the anchoring system mounted on a spreader (constant work over a limited angle of rotation without ever making any full turns, a great deal of vibration) and wear out quickly, limiting the lifetime of the anchoring system. Alternatively, the choice can be made to overdimension the roller bearings – in other words to use larger bearings with balls which are also larger – so that said roller bearings are capable of withstanding the heavy static loads to which they are subjected on the anchoring system in operation, due to the fact of working over a limited angle of rotation, without excessively reducing the lifetime of the anchoring system. However, the bearings thus overdimensioned are more expensive and bulkier. Contrariwise, torsion springs, conventionally used in anti-vibration pads, are perfectly suited to such operating conditions.

Preferably, the damper of the torsion spring comprises a plurality of elastomer elements arranged between the rigid central shaft and the rigid outer shaft, for example four elastomer elements.

The term “elastomer” refers to an elastic polymer material. Natural or synthetic rubber and neoprene are examples of elastomers within the meaning of this invention.

5 Torsion springs comprising elastomer elements have several advantages over metallic springs. For example, torsion springs comprising elastomer elements have been specifically designed to resist and absorb the vibrations and constant impacts which are the conditions typically encountered by said spring when it is mounted on the frame in use on a lift machine. By comparison, steel springs, under the same conditions of vibrations and constant impacts,
10 quickly show their limitations: the constant stress incurs cracking much more quickly on metallic springs than on elastomer elements. Thus, the torsion spring comprising elastomer elements wears out less quickly than steel springs.

 Furthermore, elastomer elements have a very low sensitivity to corrosion. Thus, springs
15 comprising elastomer elements require very little maintenance and their lifetime is not reduced even when they are used in corrosive atmospheres, for example on the seashore. By comparison, the metallic spring, in particular the compression spring, is much more sensitive to corrosion and paint treatments are not enough to improve the corrosion resistance in a satisfactory manner: an impact, a nick or a paint adhesion defect can be enough to initiate the
20 corrosion phenomenon, and the cracking of the metal. Other known physio-chemical processes with the aim of increasing corrosion resistance, in particular processes comprising heating, are ruled out to avoid having an adverse effect on the characteristics of the material, in particular its ability to withstand regular deformations in compression or in elongation.

25 It is possible to dimension such a torsion spring with elastomer elements, particularly by the choice of the material and of the dimensions of the elastomer elements, so as to obtain the desired angle between the first stop position and the second stop position, for example 30°, or even 45°, and for said torsion spring to be capable of withstanding the forces to which it will be subjected in use on the lift machine without affecting the bulk of said torsion spring on the
30 frame and without harming the manufacturability of said torsion spring. In the case of the compression spring, increasing the strength of the compression spring involves an increase in the wire diameter of the compression spring and therefore its bulk, along with its difficulty of manufacturing.

35 Finally, unlike the metallic spring, a torsion spring comprising elastomer elements is more resistant to overloads than a metallic spring and the failure of an elastomer element makes it possible to continue to operate in a fail-soft mode, whereas the breaking of the metallic spring of a torsion spring or of a compression spring, which is single, immediately shuts down the

system. Operation in fail-soft mode makes it possible to continue to operate, where applicable at a reduced speed, until the replacement of the defective part can be organized.

Each elastomer element serves not only as a spring producing a return force proportional to the angle of torsion which compensates for the variation of forces in the cable, but also as a damper which produces a dissipative force proportional to the speed of the torsional movement, which makes it possible to avoid an arrival at the stops at full speed. Thus, and unlike the compression spring and the metallic torsion spring, the torsion spring comprising such elastomer elements advantageously makes it possible to avoid adding another damper such as a hydraulic, pneumatic, metallic or elastic (tensioner) damper.

More precisely, with reference to figure 6, each torsion spring 10 may comprise a first metallic and hollow square-based prism 11, a second metallic and hollow square-based prism 12 housed inside the first prism 11 with an angular offset with respect to the first prism 11 forming the central shaft, and each elastomer element can be a cylinder 13 arranged between the first prism 11 and the second prism 12, in each corner of the first prism. In this case, the first prism 11 can be rigidly connected to the frame (reciprocally to the drum), and the second prism 12 to the drum (reciprocally to the frame). Such a configuration of the torsion spring comprising a second prism housed inside a first prism and an elastomer element in each corner of the first prism advantageously makes it possible to obtain a large angle of travel, in the order of 30° per torsion spring.

In the particular configuration in which two torsion springs are mounted in series, the inner second prism 12 of the first torsion spring can be connected to the inner second prism 12 of the second torsion spring. The outer first prisms 11 of the first and of the second torsion spring may themselves be connected to the drum and to the frame respectively. Such a configuration of the first prisms 11 and second prisms 12 is particularly advantageous, since each first prism 11 can be very easily attached to the drum, or to the frame respectively, for example by way of a strap and two assemblies comprising bolts or rivets or a weld. Furthermore, the second prisms 12 can be easily connected by techniques known to those skilled in the art, for example by way of a shaft with a square base and two axial stops.

Alternatively, the first prism 11 of the first torsion spring can be connected to the first prism 11 of the second torsion spring and the second prism 12 of the first torsion spring and the second prism 12 of the second torsion spring can be connected to the drum and to the frame respectively.

Again alternatively, the first prism 11 of the first torsion spring can be connected to the frame, respectively to the drum, and the second prism 12 of the second torsion spring can be connected to the drum, respectively to the frame, the second prism 12 of the first torsion spring being connected to the first prism 11 of the second torsion spring.

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Torsion springs making it possible to both guide the rotation of the drum about the axis of rotation (X) and to compensate for the variation in the cable tension are non-limiting of the scope of the invention. The invention extends to any anchoring system comprising such a torsion spring configured to guide the rotation of the drum and compensate for the variation in the tension of the cable.

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In addition to the embodiments of the cable anchoring system previously described, each spring may comprise two sets of springs mounted in parallel, a first part of the first set of springs and of the second set of springs being connected to the frame and a second part of the first set of springs and of the second set of springs being connected to the drum, each of the first and second sets of springs being able to be understood as a single spring or as at least two series-mounted springs. For a same angle of rotation of the drum about the axis (X), parallel mounting advantageously makes it possible to avoid doubling the force of the springs. Furthermore, parallel mounting makes it possible to distribute the forces taken up on the frame on either side of the drum and thus to minimize shear forces on the springs.

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By way of example, figures 7A to 7D show the particular configuration in which the spring comprises a first set of springs composed of a first torsion spring 10a series-mounted with a second torsion spring 10b and a second set composed of a third torsion spring 10c series-mounted with a fourth torsion spring 10d, the first set and the second set of springs being mounted in parallel with one another. Furthermore, the four springs are arranged along the axis of rotation (X). In particular, figure 7B shows the configuration in which the drum is in the neutral position. Figure 7C shows the scenario of under-tension of the cable. Figure 7D shows the scenario of over-tension of the cable.

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On Figure 7A, such a configuration of torsion springs is shown in combination with a particular embodiment of the drum according to which said drum has, in the plane (P), an ellipse shape and the axis of rotation (X) intersects with said plane (P) at the center of the circle tangent to the winding and/or unwinding portion of the cable of radius equal to the bend radius of said portion. However, any combination of torsion spring in combination with a drum having any other shape remains within the field of the invention.

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As previously mentioned, the first stop position and the second stop position may correspond to the limit angles of torsion of the torsion spring or of the set of torsion springs. Alternatively, the first stop position and the second stop position can be slightly offset so as to never reach the limit angles of torsion of the torsion springs, for example by means of rubber mechanical stops as previously described.

The invention also relates to a lifting device comprising:

- a spreader,
- an anchoring system, comprising a frame and a drum as previously described, the frame being attached to the spreader and the drum to the frame,
- a winder suitable for being attached to the lift machine,
- a cable, a first end of the cable being anchored to the drum of the anchoring system by fixed winding of at least two turns around the lateral surface of the drum and a second end of the cable being wound around the winder.

Finally, the invention relates to a lift machine comprising a lifting device as previously described. According to a particular embodiment of the invention, the lift machine is a crane, a gantry or a forklift truck. The lift machine is for example a crane used for loading or unloading containers on a container ship.

According to a particular embodiment of the lift machine, said lift machine further comprises the lifting device as previously described, a second spreader and an intermediate platform. For example, the lift machine is an STS crane and the spreader of the lifting device is used to move a container between the ship and the intermediate platform while the second spreader is used to move said container between the platform and the dock.

In a particular embodiment of the lift machine with two spreaders, the second spreader is contained in a second lifting device, said second lifting device being able to be embodied according to any of the embodiments of the lifting device previously described.

Alternatively, the lift machine does not comprise any second winder, such that the second spreader is not powered by a cable connected to a winder. For example, the second spreader is powered by a second cable deposited in a basket.

CLAIMS

1. A cable (3) anchoring system, comprising:
 - a frame (2),
 - 5 - a drum (1) mounted rotatably on the frame about an axis of rotation (X), the drum having a lateral surface (S) around an axis (Y) parallel to the axis of rotation (X), the drum being suitable for allowing travel of the cable by the winding and/or unwinding of said cable along a portion of the lateral surface, by the rotation of said drum about the axis of rotation (X) in response to a variation in the mechanical tension of the cable,
 - 10 - at least one torsion spring (10, 10a, 10b, 10c, 10d) arranged between the drum and the frame so as to compensate for the variation in the tension of the cable.

2. The cable anchoring system as claimed in the preceding claim, wherein the at least one torsion spring comprises a first part mounted on the frame and a second part mounted on

15 the drum, the second part being suitable for pivoting with respect to the first part.

3. The cable anchoring system as claimed in claim 1, comprising at least two torsion springs disposed in series.

- 20 4. The cable anchoring system as claimed in the preceding claim, wherein a first part of a first spring is mounted on the frame, a first part of a second spring is mounted on the drum, and a second part of the first spring is rigidly connected to a second part of the second spring

5. The cable anchoring system as claimed in one of claims 1 to 4, wherein each

25 torsion spring (10) comprises a rigid and hollow outer shaft (11), a rigid central shaft (12) housed inside the outer shaft (11), and a damper configured to damp a torsional movement of the rigid and hollow outer shaft in relation to the rigid central shaft.

6. The cable anchoring system as claimed in the preceding claim, wherein the

30 damper of the torsion spring comprises a plurality of elastomer elements (13) arranged between the rigid central shaft (12) and the rigid and hollow outer shaft (11).

7. The cable anchoring system as claimed in the preceding claim, wherein each

torsion spring comprises a first metallic and hollow square-based prism forming the rigid and

35 hollow outer shaft, a second prism forming the central shaft arranged in the first prism with an angular offset with respect to the first prism, and in which each elastomer element is a cylinder arranged between the first prism and the second prism, in each corner of the first prism.

8. The cable anchoring system as claimed in the preceding claim, comprising two torsion springs in series, the second square-based prism of the first torsion spring being connected to the second square-based prism of the second torsion spring.

5 9. The cable anchoring system as claimed in one of the preceding claims, wherein the at least one torsion spring is configured to damp the forces generated by the rotation of the drum about the axis of rotation (X) between a first stop position of the drum and a second stop position of the drum, the first stop position and the second stop position being angularly offset with respect to the axis of rotation (X) by an angle between 0° and 90°, preferably between 0°
10 and 60°.

10 11. The cable anchoring system as claimed in one of the preceding claims, comprising at least two sets of torsion springs disposed in parallel, a first part of each set of torsion springs being mounted on the frame and a second part of each set of springs being mounted on the
15 drum.

11. The cable anchoring system as claimed in one of the preceding claims, further comprising a compression spring and/or a tension spring comprising a first part mounted on the frame and a second part mounted on the drum.
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12. A lifting device comprising:
- a spreader (4) comprising at least one member for fastening a load to be lifted,
- a cable anchoring system as claimed in one of the preceding claims comprising a frame (2) and a drum (1), the frame being attached to the spreader and the drum being attached to the
25 frame,
- a winder suitable for being attached to a lift machine,
- a cable (3), a first end of the cable being anchored to the drum (1) of the anchoring system by a fixed winding of at least two turns around the lateral surface of the drum and a second end of the cable being wound around the winder.
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13. A lift machine (6), such as a crane, a gantry or a forklift truck, comprising a lifting device as claimed in claim 12.