

CENTRIFUGAL BRAKE MECHANISM

TECHNOLOGICAL FIELD

The present invention is generally in the field of centrifugal brakes usable for controlled descent devices.

5 BACKGROUND

In today's urban environments, many people live or work in multi-storied buildings such as sky-scrapers. In case of a fire or terrorist attack, rapid descent from upper floors of such buildings may be necessary. In such emergency situations, use of an elevator may be unsafe. Emergency stairwells may become blocked by fire or smoke,
10 making rapid escape difficult. Descent devices may be used in such emergency situations to allow a rescuee to be safely lowered to the ground.

Some patent publications relating to brake mechanisms usable for controlled descent device (CDD) applications are briefly described below.

US Patent publication No. 2010/181145 describes a descent device comprising a
15 hollow spool rotatable about a rotational axis and a lifeline, in the form of a braided steel cable, wound about the spool. A centrifugal brake mechanism including a brake assembly, comprising a pair of brake shoes and associated brake pads, is engageable with the spool to apply a braking force to the spool as the spool rotates. Biasing members, in the form of compression springs, extend between the brake shoes for
20 biasing the brake shoes and pads into engagement with the spool.

US Patent publication No. 2004/245048 describes a rappelling device for permitting persons to be rescued from high buildings, towers, and the like, having a suspension strap, suspension vest, or the like, to be worn by the person in question, wherein a rope container having a device to release the rope length is provided on the
25 suspension strap, which solution is supposed to be easy to operate, on the one hand, and to be made available to the persons in question at any time, and easy to handle for them, whereby the person using the device can essentially move both hands freely, in a stable rappelling position. This is achieved in that the rope drum that forms the rope container, in the wearing position on the back of the person using the device, is provided with a
30 rope guide device for passing the rope to a release position in the chest region of the person using the device.

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International Patent Publication No. WO 03/055560 discloses an abseiling device used as rescue equipment in disaster situations, particularly fires in buildings or tall buildings, comprising a harness for supporting particularly a person, a housing provided with a rope drum and an automatic braking device, and a rope, one end of which is fixed to the building and the other end of which is fixed to the housing. The housing is connected to the harness so as to form a unit.

International Patent Publication No. WO 89/00063 describes a lowering device particularly for assisting persons to escape from multi-storied buildings in an emergency situation, and adapted to engage a cable or rope of twisted configuration. The device comprises an inner rotatable sleeve surrounding and engaging the cable to follow the twist therein and rotate about the cable as it descends down the cable. The inner sleeve is contained within an outer housing which, in turn, supports a person, and the speed of rotation of the inner sleeve and thus the rate of descent of the device down the cable is controlled by a centrifugal brake having bell cranks carried by the inner sleeve and each pivotable against tension springs under centrifugal force to cause eccentrics on the ends of the cranks to act on brake shoes which engage a brake surface on part of the outer housing. Also disclosed is a device which, as an alternative, involves braking by utilizing a hydraulic system with a closed circuit gear pump driven by the inner sleeve and containing a variable constricted orifice to control the speed of the pump and therefore the rate of descent of the device.

The slow descender described in US Patent No. 3,946,989 includes a rope pulley and a braking apparatus which restricts the rotation speed of the rope pulley. The braking apparatus includes a mechanical braking device containing a centrifugal brake which has centrifugal weights, a V-shaped lining part cooperating with the weights, and a speed multiplying gearing device connecting the rope pulley and the centrifugal friction brake. The slow descender further includes an oil hydraulic braking device of the vane pump type or of the inscribed gear pump type.

US Patent No. 4,986,390 describes a small and light slow-descending device that anybody can easily carry in a traveling bag, or the like. Therefore, it is useful as an emergency evacuation device which enables to escape from a fire in a hotel, apartment house, office building, etc., or from a disaster in a high level road or highway, etc.

GENERAL DESCRIPTION

There is a need in the art for compact and efficient centrifugal brake mechanisms for a controlled descent device configured to be attached to a harness wearable by a descending user and capable of rapidly damping angular velocity of a rotating body (*e.g.*, a wheel, drum, or cable reel) of the device. Embodiments of the centrifugal brake mechanism of the present invention are particularly beneficial for drum devices of controlled descent devices (CDDs) configured to regulate the speed release of a cable spooled in the drum device, and guarantee continuous cable release from the device until reaching safe ground, and prevent suspension trauma. For this purpose a friction enhancement mechanism is used in some embodiments for increasing friction forces in response to increase in angular velocity of the cable drum.

The centrifugal brake mechanism of the present invention is configured to allow substantial reduction of the geometrical dimensions of the drum device by compactly arranging its components inside a circular central cavity formed inside a cable reel/drum, of the drum device, on which the cable is spooled. Brake elements (*e.g.*, brake shoe arrangements) mounted inside the central cavity are slidably coupled to a rotatable axle/shaft coaxially mounted inside the cable reel, and a planetary gear system is used to transfer rotations of the cable reel into counter-rotations of the axle. This configuration causes the brake elements to rotate inside the central cavity in a direction opposite to the direction of the rotation of the cable reel, and responsively to radially slide outwardly towards an inner wall of the cable drum due to centrifugal forces applied over them, and exert friction forces which slow down the angular speed of the cable drum.

In some embodiments the brake elements are mounted inside the cavity for radial movement over two or more parallel shaft rods attached to the axle. As the brake elements slide over the shaft rods distally away from the axle their front faces become pressed against the inner wall of the cavity and apply friction forces thereover, thereby damping the angular velocity of the cable drum and consequently slowing down the descent speed.

In some embodiments the brake mechanism comprises a friction enhancement mechanism configured to damp the angular speed of the drum by increasing the contact surface area of the braking elements used to apply the friction forces. The friction enhancement mechanism is preferably configured to provide engagement between one

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or more circular rails and corresponding one or more curved grooves engageable with said one or more circular rails, provided on the brake elements and on the inner wall of the cable drum. In this way, the friction forces evolving between the brake elements and the inner wall of the wheel are progressively increased responsive to increase in angular
5 velocity of the wheel. Particularly, in addition to the friction obtained between the front faces of the brake elements and the inner wall of the cable drum, as the angular speed of the cable drum is increased, the circular rails progressively become engaged in the curved grooves, which adds to the friction forces a progressively increasing friction component.

10 The one or more curved grooves may be provided on the front faces of the brake elements and/or on the inner wall of the cable drum, and one or more corresponding circular rails may be provided on the inner wall of the cable drum and/or on the front faces of the brake elements. For example, in some embodiments the front faces of the brake elements comprise one or more curved grooves and the inner wall of the cable
15 drum comprises one or more circular rails radially protruding inwardly from the inner wall of the cavity, each circular rail configured to become engaged inside curved grooves of the brake elements, while the respective brake elements contact the inner wall.

In one aspect there is provided a centrifugal brake mechanism for a controlled
20 descent device and being configured to be attached to a harness wearable by a descending user. The centrifugal brake mechanism comprises a support structure configured for attachment to the harness, a circular wheel having a circular central cavity and being attached to the support structure to allow it to be rotated about an axis of rotation of the wheel, an axle mounted inside the central cavity and configured and
25 operable to rotate about the axis of the wheel thereinside and comprising two or more parallel shaft rods attached thereto and extending substantially perpendicular to the axis of rotation, a gear system configured and operable to transfer rotations of the wheel into counter-rotations of the axle, one or more brake elements each having two or more pass-through bores for slidably mounting inside the central cavity over the two or more
30 parallel shaft rods and configured to radially slide towards an inner wall of the wheel encircling the cavity in response to the counter-rotations of the axle and contact and apply friction forces over the inner wall by a front face thereof.

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The centrifugal brake mechanism further comprises two or more springs mounted over at least one of the shaft rods between the brake element and the axle. A friction enhancement mechanism is used in some embodiments for increasing friction forces responsive to increase in angular velocity of the wheel. The friction enhancement mechanism is configured for providing additional engagement between the circular wheel and the brake elements by one or more circular rails and corresponding one or more curved grooves engageable with said one or more rails. The friction enhancement mechanism is configured to progressively increase friction between the brake elements and the inner wall of the wheel responsive to increase in angular velocity of the wheel.

10 In some possible embodiments the friction enhancement mechanism is implemented by one or more curved grooves provided in the each brake element and one or more circular rails provided in the inner wall encircling the cavity. The circular rails are configured to be received inside one of the curved grooves when the brake elements contact the inner wall, to thereby increase the applied friction forces. The one or more curved grooves form in some embodiments shoulder structures in the outer faces of the brake elements, and each of the one or more circular rails can be formed by two circular grooves formed in the inner wall. In this way, each circular groove is configured to receive one of the shoulder structures of the brake elements when the brake elements contact the inner wall, to thereby increase the applied friction forces.

20 Geometrical shapes of at least one of the curved grooves and of a respective one of the circular rails configured to be received in it, may be adapted to progressively increase the contact surface area of the respective brake element according to the speed of rotation of the wheel, to thereby increase the friction forces responsive to increase in angular velocity of the wheel. Additionally or alternatively, one of the one or more curved grooves may comprise a tapering groove section in which opposing sides of the groove taper towards the axis of rotation, and at least one of the one or more circular rails may comprise a corresponding tapering rail section configured to be received inside the tapering groove section.

Optionally, and in some embodiments preferably, the gear system is a planetary gear comprising a sun-gear fixedly attached to the axle, one or more planet gears attached to said support member and meshing with the sun-gear, and a ring-gear formed over a portion of the inner wall of the cavity and meshing with said one or more planet gears. In some embodiments, the gear system is configured to rotate the axle during

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rotation of the wheel in an angular velocity whose magnitude is greater than the magnitude of the angular velocity the wheel. For example, and without being limiting, a speed ratio of the gear system may be about 1 to 5.3.

In another aspect there is provided a drum device for controlled release of a
5 cable spooled therein and anchored to an external support by a free end thereof, and being configured to be harnessed to a descending user for guaranteeing continuous descent of the user while preventing suspension trauma. The drum device comprising a housing having a cable release opening for passage of released cable portions therethrough, and the centrifugal brake mechanism as described hereinabove or
10 hereinbelow. For example, the drum device comprises a cable reel on which the cable is spooled, and the cable reel is mounted inside the housing for rotation about an axis thereof during the release of the cable through the opening, an axle mounted inside a central cavity of the cable reel and configured to rotate thereinside about the axis of the wheel, a gear system configured and operable to transfer rotations of said cable reel into
15 counter-rotations of said axle, and one or more brake elements slidably coupled to the axle inside the central cavity and configured and operable to radially slide towards an inner wall of the cable reel encircling the cavity in response to the counter-rotations of the axle, and to contact and apply friction forces over the inner wall.

The brake elements and inner wall of the wheel are adapted in some
20 embodiments to implement a friction enhancement mechanism implemented by one or more curved grooves and corresponding one or more circular rails, as described hereinabove and hereinbelow. Similarly, geometrical shapes of at least one of the curved grooves and of a respective one of the circular rails may be adapted to progressively increase the contact surface area of the respective brake element
25 according to the speed of rotation of the wheel, to increase the friction forces responsive to increase in angular velocity of the wheel. At least one of the one or more curved grooves may comprise a tapering groove section, and at least one of the one or more circular rails may comprise a corresponding tapering rail section, as described hereinabove and hereinbelow.

30 The drum device may comprise one or more shaft rods attached to the axle substantially perpendicular to the axis of rotation, and each brake element may comprise one or more pass-through bores for slidably mounting it over the shaft rods for it to radial slide thereover. One or more return springs, each spring being mounted over one

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of said one or more shaft rods, may be used to mechanically couple between the axle and the brake element mounted over the shaft rod.

In some embodiments a cable-release system is used to receive released cable portions from the circular wheel and direct the released cable portions in an outward
5 direction towards the cable release opening of the drum device, and prevent backward movement of the released cable into the housing. For example, and without being limiting, the cable-release system may comprise a first cable-release unit mounted above the cable reel and having a slender opening defined between two rotatable roller shafts for passage of the released cable portions therethrough. Optionally, and in some
10 embodiments preferably, the two rotatable roller shafts of the first cable-release unit are set with substantially different diameters according to a predetermined bend radius of the cable.

The cable-release system may comprise at least one additional cable-release unit having a slender opening defined between two rotatable roller shafts for passage of the
15 released cable portions therethrough, where the at least one additional cable-release unit is mounted above and substantially in parallel to the first cable-release unit. Optionally, and in some embodiments preferably, orientation of the two rotatable roller shafts of the first cable-release unit is substantially perpendicular to orientation of the two rotatable roller shafts of the at least one additional cable-release unit.

20 In yet another aspect there is provided a controlled descent device comprising a wearable harness, a support structure attached to the harness and comprising a cable release opening for passage of portions of a spooled cable therethrough, and a drum device comprising the spooled cable and a brake mechanism configured to regulate the speed release of the cable from the drum device. In some embodiments the brake
25 mechanism comprises a circular wheel configured to rotate about an axis of rotation thereof and having a circular central cavity, an axle extending along and rotatable about said axis of rotation inside the central cavity, two or more parallel shaft rods attached to the axle and extending substantially perpendicular to the axis of rotation inside the cavity, a gear system configured to transfer rotations of said wheel into counter-
30 rotations of said axle, and one or more brake elements mounted on said two or more parallel shaft rods.

Optionally, and in some embodiments preferably, each brake element has two or more pass-through bores for slidably moving along the two or more parallel shaft rods

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inside said central cavity. Two or more springs are mounted over at least one of the shaft rods between the brake element and the axle, and the one or more brake elements are configured to radially slide over the parallel shaft rods towards the inner wall of the wheel encircling in response to counter-rotations of said axle.

5 The controlled descent device comprises in some embodiments a friction enhancement mechanism configured to increase friction forces between the brake elements and the inner wall of the wheel responsive to increase in angular velocity of the wheel. The friction enhancement mechanism is configured to provide additional engagement between the circular wheel and the brake element using one or more
10 circular rails and corresponding one or more curved grooves engageable with the one or more rails, to thereby progressively increase friction between the brake elements and the inner wall of the wheel responsive to increase in angular velocity of the wheel. Thus, the friction enhancement mechanism further substantially facilitates prevention of suspension trauma to a descending user harnessed to the controlled descent device.

15 In some applications the controlled descent device comprises a cable-release system configured to receive released cable portions from the circular wheel and direct the released cable portions in an outward direction towards the cable release opening of the drum device, and prevent backward movement of the released cable into the housing. Optionally, and in some embodiments preferably, the cable-release system
20 comprises first and second cable-release units mounted in parallel above the circular wheel, each cable-release unit having a slender opening defined between two rotatable roller shafts thereof for passage of the released cable portions therethrough. Optionally, the orientation of the rotatable roller shafts of the first cable-release unit is substantially perpendicular to orientation of the rotatable roller shafts of the second cable-release
25 unit.

BRIEF DESCRIPTION OF THE DRAWINGS

In order to understand the invention and to see how it may be carried out in practice, embodiments will now be described, by way of non-limiting example only, with reference to the accompanying drawings. Features shown in the drawings are
30 meant to be illustrative of only some embodiments of the invention, unless otherwise implicitly indicated. In the drawings like reference numerals are used to indicate corresponding parts, and in which:

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Fig. 1 exemplifies use of a CDD by a rescuee descending from a multi-storied building according to some possible embodiments;

Fig. 2 shows a perspective view of a drum device of the CDD according to some possible embodiments;

5 **Fig. 3** shows a perspective view of the drum device without one of its covering plates;

Fig. 4 shows a sectional view of the drum device without its covering plate;

Figs. 5A and **5B** are exploded views showing internal components of the drum device from two different sides thereof;

10 **Fig. 6** shows an elevated perspective view of a cable reel of the drum device and internal components thereof mounted thereinside;

Fig. 7 shows a top perspective view of the drum device without one of its side cover plates and the cable reel;

15 **Fig. 8** shows a sectional side view of the inner wall of the cable reel and of a brake shoe according to some possible embodiments;

Fig. 9 shows a perspective view of a possible arrangement of the drum device according to some possible embodiments; and

20 **Figs. 10A** and **10B** show another possible embodiment of the drum device, wherein **Fig. 10A** is a perspective view of the drum device accommodated inside housing and **Fig. 10B** shows an exploded perspective view of the drum device without the housing.

DETAILED DESCRIPTION OF EMBODIMENTS

25 The various embodiments of the present invention are described below with reference to the drawings, which are to be considered in all aspects as illustrative only and not restrictive in any manner. Elements illustrated in the drawings are not necessarily to scale, emphasis instead being placed upon clearly illustrating the principles of the invention. This invention may be provided in other specific forms and embodiments without departing from the essential characteristics described herein.

30 **Fig. 1** exemplifies use of a CDD **9** according to some possible embodiments. In this non-limiting example, a rescuee **7** escaping a high structure **3** (*e.g.*, building) safely descends from the structure by controlled release of a cable **4** spooled in the CDD **9**. The CDD **9** comprises a harness **6** (*e.g.*, type of adjustable quick fit harness) worn by

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the rescuee **7**, and a drum device **5** attached to the backside (back piece) of the harness **6**, at the upper back area of the rescuee **7** (*e.g.*, between the shoulder blades of the rescuee **7**). The drum device **5** includes a spooled cable **4**, a cable drum (also referred to herein as cable reel) **47** on which the cable **4** is spooled, and a centrifugal brake mechanism **5m** configured to regulate the rate of cable release from the drum device **5** and thereby guarantee safe descent of the rescuee **7** to the ground **2**. The spooled cable **4** is attached at one end to the cable reel **47** and includes an anchor fastener **4h** (*e.g.*, a snap hook) attached to its free end.

As shown in **Fig. 1**, in order to escape the structure **3** (*e.g.*, in an emergency situation, such as spreading fire) the rescuee **7** wears the harness **6**, secures the anchor fastener **4h** to an anchor member **3r**, preferably an anchor fixture fixedly attached to the structure **3** (*e.g.*, anchor ring), and exits the structure **3** *e.g.*, through an opening **3w** such as a window, exit/escape door, or the like. After exiting the structure **3** the rescuee **7** is pulled downwardly by gravity (shown by arrow **1**) towards the ground **2** and the spooled cable **4** is progressively released from the drum device **5** as the rescuee **7** descends downwardly towards the ground **2**. In this non-limiting example the harness **6** and drum device **5** arrangement guarantees that orientation of the body of the rescuee **7** during the fall is substantially vertical relative to the ground **2**. The brake mechanism **5m** provided in the drum device **5** is configured to controllably release the spooled cable **4** within predefined release speed rates and thereby maintain a substantially controlled descent speed (*e.g.*, of about 0.7 to 2 m/sec for a rescuee weight between 30 to 135 Kg) of the rescuee **7**, until safely reaching the ground **2**.

The CDD **9** shown in **Fig. 1** exemplifies a possible embodiment wherein the drum device **5** is mounted substantially perpendicular to a back piece of the harness **6**, such that the plane of rotation of the cable reel **47** substantially resides in (or parallel to) a median plane of the rescuee **7**. It is however noted that other arrangements of the harness **6** and the drum device **5** are also possible, without departing from the scope and spirit of the present invention. For example, and without being limiting, in some possible embodiments the drum device **5** may be mounted substantially parallel to the back piece (*i.e.*, such that the plane of rotation of the cable reel **47** is substantially parallel to a frontal plane of the rescuee **7**) and/or over a lower back area of the harness (*e.g.*, below the shoulder blades of the user). Alternatively, in some possible embodiments the drum device **5** is mounted over a frontal piece of the harness such that

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the rotation plane of the cable reel **47** is substantially parallel (or perpendicular) to a frontal plane of the rescuer **7**.

Fig. 2 shows a perspective view of the drum device **5** according to some possible embodiments. In this non-limiting example the drum device **5** comprises a cable reel **47** mechanically coupled to an axle (shaft) **60** passing along the axis of rotation **47a** of the cable reel **47**. The axle **60** is operably mounted for rotation inside a support structure **45** of the drum device **5**. The support structure **45** comprises two tear-shaped side cover plates, **45f** and **45r**, and upper and lower support elements (*e.g.*, rods), **45b** and **45a**, respectively, fixedly attached at their ends to the cover plates, **45f** and **45r**. The length of the support elements, **45b** and **45a**, is configured to define a gap **g** between the two side cover plates, **45f** and **45r**, sufficiently wide to accommodate the cable reel **47** and permit free undisturbed rotations thereof inside the support structure **45**. The extremities of the axle **60** are attached to the side cover plates **45f** and **45r** by bearings **45x** allowing it to freely rotate inside the support structure **45** in a plane of rotations being substantially parallel to the side cover plates.

The upper portion of the tear-like shaped support structure **45** includes a cable release mechanism for directing the release of the cable **4** from the drum device **5** and preventing backward movement of the cable **4** into the support structure. In this non-limiting example the cable release mechanism comprises two cable release units, **48** and **49**, accommodated one on top of the other between the upper portions of the cover plates, **45f** and **45r**. The cable release units **48** and/or **49** are configured and operable to direct the cable release in an outward direction towards a cable release opening **Pc** of the drum device **5**, and prevent backward movement of the released cable **4** into the drum device **5**. In this specific and non-limiting example the cable release opening **Pc** is defined by an opening of the upper cable release unit **48**.

As best seen in **Fig. 3**, the bottom cable release mechanism **49** comprises two roller shafts rotatably mounted one parallel to the other between, and perpendicular, to the cover plates **45f** and **45r**. As demonstrated in **Fig. 3**, in possible embodiments the two rollers shafts of the bottom cable release mechanism **49** are of different diameters and are configured to provide a desired bend radius. For example, and without being limiting, for a cable **4** having a diameter of about 3 mm and a bend diameter of about 32 mm, a first roller shaft **49u** of the bottom cable release mechanism **49** may be of a smaller diameter (*e.g.*, about 16 mm) relative to a second roller shaft **49v** thereof having

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a greater diameter (*e.g.*, about 32 mm). The parallel roller shafts **49u** and **49v** are mounted slightly spaced-apart above the cable reel **47**, leaving a slender gap between them sufficient for passage of the cable **4** therethrough, while contacting the roller shafts and rotating them in predetermined directions due to friction forces evolving therebetween.

The parallel roller shafts, **49u** and **49v**, may be configured to prevent movement of the cable (**4**) towards the cable reel **47** (*i.e.*, to prevent the cable from returning back into the support structure **45**), for example and without being limiting, by using a ratchet mechanism (not shown) configured to prevent rotation of the shaft rollers in a counter direction. Additionally or alternatively, backward movement of the cable **4** into the support structure may be prevented by properly setting the elasticity of the cable **4** to a desired suitable level for allowing cable deformations to occur when passing through the slender gap between the roller shafts and quick restoration of its shape upon leaving the roller shafts, and/or by applying adhesive material(s) between the cable **4** and the roller shafts of the cable release mechanism **49**, and/or by setting friction of the surface of the rollers contacting the cable **4** to a desired suitable level.

The upper cable release mechanism **48** comprises two roller shafts **48s** and **48t** rotatably mounted one parallel to the other inside a flat frame **48f**. In this specific and non-limiting example the roller shafts **48s** and **48t** of the upper cable release mechanism **48** have substantially the same diameter (*e.g.*, about 16 mm). The frame **48f** of the upper cable release mechanism **48** is mounted above the bottom cable release mechanism **49**, between and perpendicular to the cover plates, **45f** and **45r**. The frame **48f** is mounted inside the support structure **45** in a plane being substantially parallel to a plane in which the shaft rollers **49u** and **49v**, of the bottom cable release mechanism **49**, reside.

As seen in **Fig. 3**, in this non-limiting example the axes of rotations of roller shafts **48s** and **48t** of the upper cable release mechanism **48** are substantially perpendicular to the axes of rotations of the shaft rollers **49u** and **49v** of the bottom cable release mechanism **49**. The roller shafts **48s** and **48t** are mounted spaced-apart inside the frame **48f** leaving a slender gap between them sufficient for passage of the cable (**4**) therethrough, while contacting the roller shafts and rotating them in predetermined directions due to friction forces evolving therebetween. The roller shafts, **48s** and **48t**, may be configured to prevent movement of the cable (**4**) towards the cable reel **47** (*i.e.*, to prevent the cable from moving into the support structure **45**), using one

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or more of the techniques described hereinabove with reference to the bottom cable release mechanism **49** (*e.g.*, using a ratchet mechanism configured to prevent rotation of the shaft rollers in a counter direction).

In some embodiments a fastening element **5s** (*e.g.*, shackle), attached to the support structure **45**, is used to fixedly attach the drum device **5** to the harness (**6**). The fastening element **5s** may be attached to the support structure **45** by a fastening member **5r** (*e.g.*, metal ring or holed piece) suitable for attaching the fastening element **5s** to the lower support element **45a**, while permitting some rotary movement of the fastening element **5s** thereabout.

Fig. 3 shows the drum device **5** without its side cover plate **45f**, thereby exposing the arrangement of cable reel **47**, and its reel flanges **47f**, inside the support structure **45**. **Fig. 4** is a sectional view of the drum device, without the covering plate **45f** and the reel flange **47f** located beside it, thereby showing elements mounted inside the cable reel **47**.

As best seen in **Figs. 5A** and **5B**, the axle **60** comprises a sun-gear **64** fixedly attached to it, the cover plate **45r** comprises a planetary gear system **65** (*e.g.*, comprising three planet-gear wheels) rotatably attached to it, and a ring-gear **67** is formed on a portion of the inner wall **47w** of the cable reel **47** adjacent to the cover plate **45r**. Each planet-gear **65**, attached over the cover plate **45r** free to rotate about its central axis, is mechanically coupled to the sun-gear **64** fixedly mounted on the axle **60**, and to the ring-gear **67** formed on the inner wall **47w** of the cable reel **47**.

Optionally, and in some embodiments preferably, the planetary gear system **65** is designed to transfer the rotations of the cable reel **47** to the axle **60** during the cable release and cause counter rotations (*i.e.*, in opposite direction) of the axle **60** in an angular velocity (V_x in **Fig. 6**) that is greater than the angular velocity (V_r) of the cable reel **47**. For example, in use, as the cable **4** is released from the drum device **5**, the cable reel **47** rotates about the rotation axis **47a** and the ring-gear **67** formed over the inner wall **47w** of the cable reel **47** rotates the planet-gears **65** mechanically coupled to it in the same direction of rotations. In effect, the planet-gears **65** coupled to the sun-gear **64** rotate the axle **60** in a direction opposite to the direction of rotation of the cable reel **47**.

Optionally, and in some embodiments preferably, the planetary gear system **65** may be configured and operable to rotate the axle **60** during the cable release and cause counter rotations (*i.e.*, in opposite direction) of the axle **60** in an angular velocity (V_x in

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Fig. 6) whose magnitude is greater than (or equal to) the magnitude of the angular velocity (V_r) of the cable reel **47**. For example, and without being limiting, the planetary gear system **65** may be configured to provide a gear ratio of about 1 to 5.3.

In possible embodiments the diameter of the ring-gear **67** may be about 140 to 150 mm, the diameter of the planet-gears **65** may be about 50 to 70 mm, and the diameter of the sun-gear **64** may be about 25 to 35 mm. The axle **60**, rod arms **67r**, gear elements and cable reel **47**, and other parts of the CDD **9**, may be manufactured from any suitable metallic or plastic type of material capable of withstanding the forces evolving in the device during descent. For example, and without being limiting, in possible embodiments the brake shoes **62** may be manufactured from Iron, Aluminum, Brass, Stainless Steel, or combinations thereof, the cable reel **47** may be manufactured from Aluminum, plastic, fiberglass reinforced Nylon, or combinations thereof, and the cogwheels of the gear system may be manufactured from any suitable metal or plastic material. The cable **4** may be made from a fireproof material, such as a metal, for example, from steel. Alternately, the cable **4** may be made of engineering plastics, such as Kevlar®, carbon fiber, or other high strength cable material. The length of the cable may be about 50-500 meters (m), and its diameter may be about 1 to 4 millimeters.

For example, and without being limiting, in some possible embodiments: the weight of a drum device, and about 50 m of cable reeled therein, may be about 5 kilograms; the weight of a drum device, and about 100 m of cable reeled therein, may be about 7.5 kilograms; and the weight of a drum device, and about 200 m of cable reeled therein, may be about 12 kilograms. The drum device having these weight ranges may be of suitable weight for a user to lift and put on his or her back using a CDD according to embodiments of the invention.

Fig. 6 is an elevated view of the cable reel **47** without the reel flange **47f** showing components of the brake mechanism **5m** operably mounted thereinside. It is seen that the axle **60** passing along the rotation axis **47a** of the cable reel **47** comprises one or more pass-through bores **60b**, and one or more rods **67** passing through the pass-through bores **60b** fixedly attached to the axle **60**. Each rod **67** attached to the axle **60** radially extends from the axle **60** and forms two rod arms (**67r** in **Fig. 7** and **8**) extending outwardly from the axle **60** in opposite directions towards the inner wall **47w** of the cable reel **47**. One or more brake shoes **62** slidably mounted over the rod arms **67r** are mechanically coupled to the axle **60** by return springs **63** and are configured to

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slide outwardly over the rod arms **60r**, toward the inner wall **47w** of the cable reel **47**, due to centrifugal forces applied on them as the axle is rotated by the planetary-gear system **65**. Accordingly, in this non-limiting example the brake system implements a "normally disengaged" mechanism, as the return springs retract the brake shoes **62** radially towards the axle **60** when centrifugal forces are not being applied.

In this specific and non-limiting example, two parallel rods **67** are attached to the axle **60** to form two pairs of rod arms **67r** extending in opposite directions from the axle **60** towards the inner walls **47w** of the cable reel **47**. A brake shoe **62** is mounted over each pair of rod arms **67r** and is configured to slide radially thereover towards the inner walls **47w** of the cable reel **47** against pulling forces applied on the brake shoe by two return springs **63** mounted over the rod arms **67r**. Optionally, and in some embodiments preferably, the springs **63** are placed over rod arms **67r** without being attached to the brake shoes **62** or to the axle **60**. In this way, the springs **63** are used as partitioning elements for preventing contact between the brake shoes **62** and the axle **60**, and do not apply forces on the brake shoes **62** when they radially slide towards the inner walls **47w** of the cable reel **47**.

Fig. 7 shows the centrifugal brake mechanism **5m** in a rest state without the cable reel **47**, wherein the brake shoes **62** and the return springs **63** are in a retracted position adjacent to the axle **60**. When the spooled cable **4** is released from the drum device, the rotations of the cable reel **47** transferred to the planetary-gears **65** cause counter-rotations of the axle **60** and the rod arms **67r** attached to it about the rotation axis **47a**. The counter-rotations of the rod arms **67r** apply centrifugal forces on the brake shoes **62** causing radial movement of the brake shoes **62** e.g., against return forces of the return springs **63**, towards the inner wall **47w** of the cable drum **47**, until the brake shoes **62** contact the inner walls **47w** of the cable reel **47**.

As seen, the external faces (also referred to herein as front faces) **62e** (i.e., facing the inner wall **47w**) of the brake shoes **62** have a curved surface matching (i.e., being complementary to) the curvature of the inner walls of the cable reel **47**, to thereby maximize the surface contact between them when the brake shoes **62** are pressed by the centrifugal forces against the inner walls **47w**, and thereby maximize the friction forces between these surfaces. In this way, as the descent speed of the user **7** of the CDD **9** is increased during the fall, the counter-rotations of the rod arms **67r** inside the cable reel **47** are also increased, thus increasing the centrifugal forces pressing the brake shoes **62**

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against the inner walls **47w** of the cable reel **47**. Consequently, the friction forces evolving between the external surfaces **62e** of the brake shoes **62** and the inner walls **47w** of the cable reel **47** are respectively increased, which in effect decreases the angular velocity of the cable reel **47**. Correspondingly, decrease in the angular velocity
5 of the cable reel **47** slows down the speed of cable release from the drum device, which in turn slows down the descent speed of the rescuee. Accordingly, properly setting the gear ratio of the planetary gear system **65** can be used to guarantee that the angular velocity of the cable reel **47** does not exceed a predefined limit (*e.g.*, about 150 rpm), and thereby guarantee that the descent speed remains within a predetermined range
10 (*e.g.*, about 1 to 2 m/s).

In some possible embodiments the external surfaces **62e** of the brake shoes **62** are covered by one or more friction enhancing layers (pads) configured to increase the friction coefficient of the brake shoes **62** and thereby increase the friction forces evolving between the brake shoes **62** and the inner walls **47w** of the cable reel **47**, so as
15 to further slow down the speed of rotation of the cable reel **47** during descent. In other possible embodiments, the brake shoes **62** are configured to directly contact the inner wall **47w** of the cable reel **47** *i.e.*, without any friction enhancing layers.

Additionally, or alternatively, the brake mechanism **5m** may comprise a friction enhancement (speed damping) mechanism configured to significantly increase the
20 friction forces evolving between the brake shoes **62** and the inner wall **47w** of the cable reel **47**. For example, in some embodiments each brake shoe **62** comprises one or more curved (*e.g.*, arc-shaped) grooves **68** (only one curved groove is shown in the figures) formed along its external face **62e** *i.e.*, facing the inner wall **47w** of the cable reel **47**, and being substantially parallel to the plane of rotation of the cable reel **47**. The one or
25 more curved grooves **68** are designed to receive and mate with one or more circular rails **66** inwardly protruding from the inner wall **47w** of the cable reel **47** towards the axis of rotation **47a**, and being substantially parallel to the plane of rotation of the cable reel **47**. In this way, the contact surface areas of the brake shoes **62** and of the inner wall **47w** of the cable reel **47** are substantially increased during engagement of the circular rails **66**
30 in the curved grooves **68**. Accordingly, as the brake shoes **62** are pushed outwardly against the inner wall **47w** of the cable reel **47** by the centrifugal forces, greater friction forces evolve as the circular rails **66** progressively become engaged in the curved grooves **68**, in addition to the friction forces obtained between the contacting surfaces of

the front faces **62e** of the brake shoes **62** and the inner wall **47w** of the cable drum **47**. In effect, a stronger rotation speed damping effect is achieved, which in turn effectively damps the descent speed of the CDD.

It is noted that the curved grooves **68** and their respective circular rails **66** further serve as guiding means that prevent movements of the brake shoes **62** in undesired directions during engagement of the rails **66** inside the grooves **68**, and which translate rolling/tilting moments, which may be applied over the brake shoes during operation of the device, into an increase in the damping friction forces.

In some embodiments the damping friction forces are further increased by adding one or more inclined facets to the one or more curved grooves **68** and the one or more circular rails **66**. For example, and without being limiting, at least one curved groove **68** may include a tapering section wherein the sides of the curved groove gradually taper towards the axis of rotation **47a**, and a corresponding at least one circular rail **66** includes a corresponding tapering section configured to mate with the tapering section of the at least one curved groove **68**.

In some embodiments (not shown) one or more circular rails are formed on the front faces **62e** of the brake shoes **62**, and one or more corresponding curved grooves are formed in the inner wall of the drum **47**. Alternatively, in some possible embodiments, each brake element comprises one or more rails and one or more grooves, and the inner wall of the cable drum **47** comprises corresponding one or more grooves and one or more rails, configured to mate with therewith.

Fig. 8 shows a sectional side view of the wall of the cable reel **47** and of a brake shoe **62** according to some possible embodiments. In this non-limiting example the brake shoe **62** comprises two spaced apart and parallel pass-through bores **62r** configured to receive two respective parallel rod arms **67r** for slidable motion of the brake shoe **62** thereover. The return springs **63** mounted over the rod arms **67r** are configured to retract the brake shoe **62** radially towards the axis of rotation **47a** whenever the centrifugal forces acting on the brake shoe **62** are smaller than some predetermined level. The groove **68** may comprise a tapering portion **68s** followed by a slit **68e**, and the circular rail **66** protruding from the surface of the inner wall **47w** may comprise a corresponding tapering structure **66s** configured to be received inside the tapering portion **68s** of the groove **68**. The tapering portion **68s** of the groove **68** and the tapering structure **66s** of the circular rail **66** may have the same taper-angle α (e.g.,

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about 30° to 90°). It is however noted that in possible embodiments the different (or slightly different) taper-angles may be used for the tapering portion **68s** of the groove **68** and for the tapering structure **66s** of the circular rail **66**.

The slit portion **68e** of the groove **68** may be configured to allow further
5 advancement of the tapered rail **66** thereinto in response to increase in the centrifugal forces applied over the brake shoe **62**. For example and without being limiting, layers of the external faces **62e** of the brake shoe **62**, and/or of the inner wall **47w** of the cable reel **47**, may be grinded during the descent, and in this event the apex of the tapered rail **66** may be further advanced into the slit portion **68e** of the groove **68**, thereby
10 compensating for the grind layers by allowing expansion of the groove **68** and in effect increasing the friction between the brake shoe **62** and the inner wall **47a**.

As also seen in **Fig. 8**, the circular rail **66** protruding from the inner wall **47w** of the cable reel **47** forms two circular grooves, **7a** and **7b**, configured to receive respective shoulder structures, **62a** and **62b**, of the brake shoe **62**. In this specific and
15 non-limiting example the shoulder structures **62a** and **62b** are relatively symmetric and have a right-trapezoidal sectional shape.

Fig. 9 shows a perspective view of a possible arrangement of a drum device **5''** according to some possible embodiments. In this non-limiting example an additional cable release unit **80** is separately mounted above cable release opening **Pc** of the drum
20 device **5''**. Particularly, the additional cable release unit **80** is mounted on a support member **81** and placed spaced-apart above the top cable release unit **48** of the drum device **5''**. As seen, the additional cable release unit **80** is substantially parallel to, and aligned with, the top cable release unit **48**, and the orientation of its two rollers shafts, **80s** and **80t**, is substantially parallel to the orientation of the two rollers shafts **48s** and
25 **48t** of the top cable release unit **48**, to thereby guide the released cable **4** vertically/upwardly and prevent it from contacting the harness **6** and/or the rescuee **7**. This arrangement of the roller shafts **48s** and **48t** being parallel to the back piece, also substantially prevents movement of the released cable towards the body of the rescuee.

For example, and without being limiting, the drum device arrangement shown in
30 **Fig. 9** may be used in a harness arrangement of a CDD. The drum device **5''** may be secured to a back-piece of the harness (*e.g.*, between the shoulder blades of the user), and the support member **81** may be mounted on the back-piece above the drum device **5''** (*e.g.*, above shoulder blades). In this configuration the additional cable release unit

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80 is mounted on the separate support member **81**, and it thus can move relative to drum device **5'** and thereby facilitates in absorbing shocks and in distributing fall energy.

Fig. 10A shows a possible embodiment of a drum device **5'** mounted inside a housing **96**. The housing **96** is configured to accommodate the drum device with the 5 spooled cable **4**, as exemplified in any one of the figures described hereinabove or hereinbelow. The housing **96** comprises a cable release opening **Pc** for passage of released cable portions therethrough and several fastening holes **98f** provided at boundaries of a support plate **98** attached to the drum device **5'**.

Fig. 10B shows an exploded perspective view of the drum device **5'** without the 10 housing **96** and with the cover plate **45r** slightly elevated. As seen, in this non-limiting example one cable release unit **49** is used in the drum device **5'**, where the roller shafts of the cable release unit **49** are attached to the cover plates **45f** and **45r**, beneath the cable release opening **Pc** and substantially perpendicular to the cover plates. In this possible embodiment the cable reel **47** is mounted within a gap **g** defined between two 15 three-apex star-shaped plates **93a** and **93b**, which are attached to each other by support elements (*e.g.*, rods) **45b** connecting between respective apex regions thereof, and the axle **60** is attached to the star-shaped plates **93a** and **93b** by bearings **45x** for allowing it to rotate inside the drum cable reel about its axis of rotations.

The drum device **5'** comprises a gear system (not shown) and brake elements 20 (not shown) configured to regulate the cable release during the fall, as exemplified and described hereinabove. In this embodiment, however, each planet cogwheel is attached for rotation over a respective pivot **92** provided on one of the arms of the three-apex star-shaped plate **93b**.

As described hereinabove and shown in the associated Figs., the present 25 invention provides a centrifugal brake mechanism for a CDD. While particular embodiments of the invention have been described, it will be understood, however, that the invention is not limited thereto, since modifications may be made by those skilled in the art, particularly in light of the foregoing teachings. As will be appreciated by the skilled person, the invention can be carried out in a great variety of ways, employing 30 more than one technique from those described above, all without exceeding the scope of the invention.

CLAIMS:

1. A centrifugal brake mechanism for a controlled descent device, the centrifugal brake mechanism being configured to be attached to a harness wearable by a descending user, and comprising:
 - 5 a support structure configured for attachment to the harness;
a circular wheel located inside said support structure and configured and operable to rotate about an axis of rotation thereof, said circular wheel comprising a circular central cavity and an inner wall encircling the cavity;
an axle mounted inside said central cavity, the axle extending along and
10 rotatable about said axis of rotation inside said central cavity, and two or more parallel shaft rods attached to the axle and extending substantially perpendicular to the axis of rotation inside the cavity;
a gear system configured and operable to transfer rotations of said wheel into counter-rotations of said axle;
 - 15 one or more brake elements mounted on said two or more parallel shaft rods, each brake element having two or more pass-through bores for slidably moving along said two or more parallel shaft rods inside said central cavity, and two or more springs mounted over at least one of said shaft rods between the brake element and the axle, said one or more brake elements being configured and operable to radially slide over the
20 parallel shaft rods towards the inner wall of the wheel encircling said cavity in response to the counter-rotations of said axle; and
a friction enhancement mechanism for increasing friction forces responsive to increase in angular velocity of the wheel, said friction enhancement mechanism being configured for providing additional engagement between the circular wheel and the
25 brake element and comprising one or more circular rails and corresponding one or more curved grooves engageable with said one or more rails, to thereby progressively increase friction between said brake elements and the inner wall of the wheel responsive to increase in angular velocity of the wheel.
2. The brake mechanism of claim 1 wherein the one or more curved grooves
30 form shoulder structures in the outer faces of the brake elements and each of the one or more circular rails is formed by two circular grooves formed in the inner wall, each

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circular groove being configured and operable to receive one of said shoulder structures of the brake elements when said brake element contacts the inner wall, to thereby increase the applied friction forces.

3. The brake mechanism of claim 1 wherein geometrical shapes of at least one
5 of the curved grooves and of a respective one of the circular rails configured to be received in it, are adapted to progressively increase the friction forces responsive to increase in angular velocity of the wheel.

4. The brake mechanism of claim 3 wherein at least one of the one or more
10 curved grooves comprises a tapering groove section in which opposing sides of the groove taper towards the axis of rotation, and at least one of the one or more circular rails comprises a corresponding tapering rail section configured to be received inside said tapering groove section.

5. The brake mechanism of claim 1 wherein the gear system is a planetary gear
15 system configured and operable to rotate the axle during rotation of the wheel in an angular velocity whose magnitude is greater than the magnitude of the angular velocity of the wheel.

6. The brake mechanism of Claim 5 wherein a speed ratio of the planetary gear system is about 1 to 5.3.

7. A drum device for controlled release of a cable spooled therein and anchored
20 to an external support by a free end of said cable, said drum device is configured and operable to be harnessed to a descending user for guaranteeing continuous descent of the user while preventing suspension trauma, the drum device comprising the brake mechanism according to claim 1, and the support structure of the drum device has a cable release opening for passage of released cable portions therethrough.

25 8. The drum device of claim 7 comprising a cable-release system configured and operable to receive released cable portions from the circular wheel and direct the released cable portions in an outward direction towards the cable release opening of the drum device, and prevent backward movement of the released cable into the housing.

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9. The drum device of claim 8 wherein the cable-release system comprises a first cable-release unit mounted above the circular wheel and having a slender opening defined between two rotatable roller shafts thereof for passage of the released cable portions therethrough.
- 5 10. The drum device of claim 9 wherein diameters of the two rotatable roller shafts of the first cable-release unit are substantially different, and wherein the diameter of one of said rotatable roller shafts is set according to a predetermined bend radius of the cable.
11. The drum device of claim 9 wherein the cable-release system comprises at
10 least one additional cable-release unit having a slender opening defined between two rotatable roller shafts for passage of the released cable portions therethrough, said at least one additional cable-release unit being mounted above and substantially in parallel to the first cable-release unit.
12. The drum device of Claim 11 wherein the orientation of the two rotatable
15 roller shafts of the first cable-release unit is substantially perpendicular to orientation of the two rotatable roller shafts of the at least one additional cable-release unit.
13. A controlled descent device comprising:
a wearable harness;
a support structure attached to the harness and having a cable release opening for
20 passage of portions of a spooled cable therethrough; and
a drum device comprising the spooled cable and a brake mechanism configured to regulate the speed release of the cable from the drum device, said brake mechanism comprises: a circular wheel configured to rotate about an axis of rotation thereof and comprising a circular central cavity; an axle extending along and rotatable about said
25 axis of rotation inside said central cavity; two or more parallel shaft rods attached to the axle and extending substantially perpendicular to the axis of rotation inside the cavity; a gear system configured to transfer rotations of said wheel into counter-rotations of said axle; and one or more brake elements mounted on said two or more parallel shaft rods, each brake element having two or more pass-through bores for slidably moving along
30 said two or more parallel shaft rods inside said central cavity, and two or more springs

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mounted over at least one of said shaft rods between the brake element and the axle, said one or more brake elements being configured and operable to radially slide over the parallel shaft rods towards the inner wall of the wheel encircling said cavity in response to the counter-rotations of said axle.

5 14. The controlled descent device of claim 13 comprising a friction enhancement mechanism for increasing friction forces responsive to increase in angular velocity of the wheel, said friction enhancement mechanism being configured for providing additional engagement between the circular wheel and the brake element and comprising one or more circular rails and corresponding one or more curved grooves
10 engageable with said one or more rails, to thereby progressively increase friction between said brake elements and the inner wall of the wheel responsive to increase in angular velocity of the wheel and prevent suspension trauma.

15 15. The controlled descent device of claim 13 comprising a cable-release system configured to receive released cable portions from the circular wheel and direct the released cable portions in an outward direction towards the cable release opening of the drum device, and prevent backward movement of the released cable into the housing.

16. The controlled descent device of claim 15 wherein the cable-release system comprises first and second cable-release units mounted in parallel above the circular wheel, each cable-release unit having a slender opening defined between two rotatable
20 roller shafts thereof for passage of the released cable portions therethrough.

17. The controlled descent device of claim 16 wherein the orientation of the rotatable roller shafts of the first cable-release unit is substantially perpendicular to orientation of the rotatable roller shafts of the second cable-release unit.