



(11) **EP 2 522 616 A1**

(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
14.11.2012 Bulletin 2012/46

(51) Int Cl.:
B66B 9/02 (2006.01) E06C 7/12 (2006.01)

(21) Application number: **11165847.2**

(22) Date of filing: **12.05.2011**

(84) Designated Contracting States:
**AL AT BE BG CH CY CZ DE DK EE ES FI FR GB
GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO
PL PT RO RS SE SI SK SM TR**
Designated Extension States:
BA ME

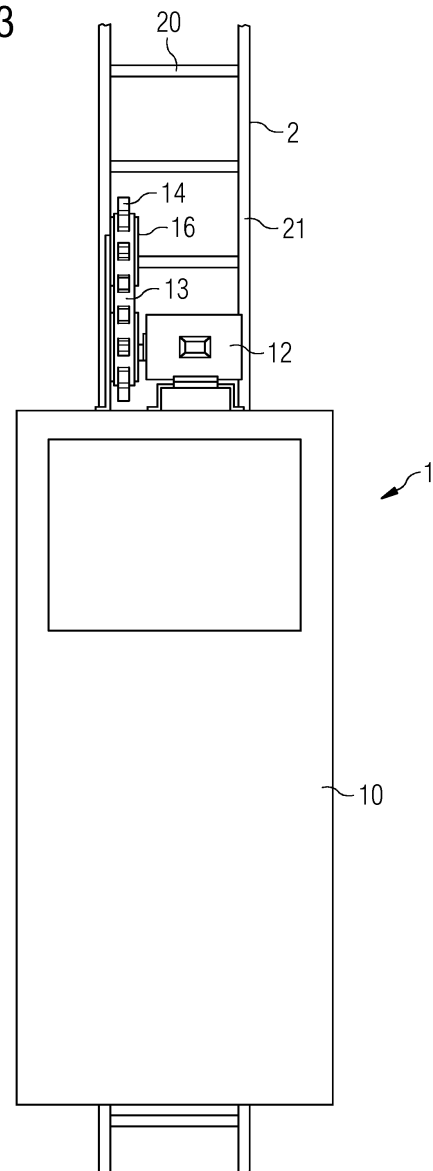
(71) Applicant: **SIEMENS AKTIENGESELLSCHAFT
80333 München (DE)**

(72) Inventor: **Hänisch, Ringo
7330, Brande (DK)**

(54) **Elevator apparatus**

(57) The invention describes an elevator apparatus (1) comprising an elevator cage (10); a guiding means (11) for guiding the elevator cage (10) along a ladder (2); a drive belt (13) comprising a plurality of climb pins (14, 14'), wherein a climb pin (14, 14') is realised to engage with a rung (20) of the ladder (2); and a motor (12) arranged on the elevator cage (10), which motor (12) is realised to drive the drive belt (13). The invention further describes a method of constructing a hollow tower (4), which method comprises the steps of constructing a lower region (40) of the tower (4); arranging a lower ladder section (24) of a ladder (2) at the level of the lower tower region (40); arranging such an elevator apparatus (1) on the lower ladder section (24); constructing an upper region (40') of the tower (4) on the lower tower region (40); and connecting an upper ladder section (24') of the ladder (2) to the lower ladder section (24) such that the elevator apparatus (1) can move an elevator cage (10) along the connected ladder sections (24, 24'). The invention also describes a hollow tower (4) comprising such an elevator apparatus (1) arranged on a ladder (2), which ladder (2) is arranged in the interior of the tower (4).

FIG 3



EP 2 522 616 A1

Description

[0001] The invention describes an elevator apparatus, a method of constructing a hollow tower, and a hollow tower comprising such an elevator apparatus.

[0002] In large structures such as wind turbine towers, a ladder is usually erected in the interior of the tower so that personnel can access equipment located in upper regions of the structure. Because a wind turbine tower can be quite high, it would be tiring as well as dangerous for service personnel to ascend and descend such a ladder 'on foot' while carrying heavy equipment such as tools and spare parts. Therefore, some prior art solutions offer various realizations combining an elevator, a traction cable, and drive unit for hoisting the elevator along the traction cable, where the elevator or service lift can be used to transport people and/or equipment with a minimum of effort. Such a personnel or service lift apparatus can be used to raise and lower one or more persons between levels in the tower, for example from ground level to the top of the tower of a wind turbine. The cable is usually anchored at the top of the tower (for example from a suspension beam) and at ground level; and a drive unit with a suitable traction sheave hoist can be mounted on or in the elevator cage to allow the elevator to travel along the cable.

[0003] Obviously, such an arrangement requires that the tower is first erected before the service lift can be put into operation. A relatively 'short' tower, such as a tubular steel tower with a height in the order of 60 to 120 m or so, can be assembled in the space of few hours by hoisting two, three or more tower sections into place using a crane. Each tower section can already comprise a corresponding pre-installed ladder section. Therefore, directly after assembly, a cable can be suspended in place so that the upper regions of such a tower can be accessed using an elevator and hoist. However, large wind turbines with very high towers use different structural technologies. For example, a very high tower in the order of 100 metres or more can be constructed in situ by casting concrete, or using a lattice or plate construction. Such a cast structure may require days or even weeks for completion. During that time, it is not possible to use the prior art hoist and cable apparatus to ascend to the only partially completed upper levels. Therefore, any work that must be carried out at the various levels within the tower, for example electrical wiring for interior tower lighting, must be postponed until the entire tower is complete and a hoisting apparatus can be put onto place, or must be carried out by accessing those levels using only a basic ladder without the benefits of a cable and hoist apparatus. Alternatively, an elevator system using a ladder with a rack and pinion could be used, but such a system requires at least one additional toothed rack arranged as a permanent fixture on the ladder, thus adding considerably to the overall cost of the construction.

[0004] It is therefore an object of the invention to provide an alternative elevator apparatus that overcomes

the problems mentioned above.

[0005] The object of the invention is achieved by the elevator apparatus according to claim 1, by the method of constructing a hollow tower according to claim 11, and the hollow tower according to claim 14.

[0006] According to the invention, an elevator apparatus - for use during construction of an edifice - comprises an elevator cage, a guiding means for guiding the elevator cage along a ladder; a drive belt comprising a plurality of climb pins, wherein a climb pin is realised to engage with a rung of the ladder; and a motor arranged on the elevator cage, which motor is realised to drive the drive belt.

[0007] An advantage of the elevator apparatus according to the invention is that it does not require any hoisting apparatus such as a winch or cable to lift or pull the elevator cage upward, or to lower the elevator cage downward. Instead, the elevator apparatus is a self-contained solution that can 'climb' up or down the ladder of an edifice, even during construction of the edifice. Also, the elevator apparatus according to the invention does not require any components that become redundant once construction of the edifice is complete, unlike the known service lift systems that require components such as a toothed rack or a suspension beam just so that the service lift can be used during construction of an edifice.

[0008] A further advantage of the elevator apparatus according to the invention is that it can be put into operation even before the ladder has reached its finished length, i.e. the elevator apparatus can be used for a partially completed ladder which is assembled piece by piece, for example at a pace corresponding to the edifice that is being constructed, and for which the ladder is to serve as an access means during construction.

[0009] According to the invention, a method of constructing a hollow tower comprises the steps of constructing a lower region of the tower; arranging a lower ladder section of a ladder at the level of the lower tower section; arranging such an elevator apparatus on the lower ladder section; constructing an upper region of the tower above the lower tower region; and connecting an upper ladder section of the ladder to the lower ladder section such that the elevator apparatus can move the elevator cage along the connected ladder sections.

[0010] The ladder sections could be lifted into place using a crane which also serves to lift material used in the construction of the hollow tower. In this way, successive ladder sections can be connected together. Usually, such a ladder is fastened using stays to a wall of the tower, so that the ladder cannot tilt away from the tower wall. While the ladder 'grows' upwards in this way, the elevator apparatus can be used to allow service personnel access to various levels of the partially completed tower and can be used to lift material and tools, so that service work can be carried out at these levels even though the tower itself is still under construction. In this way, significant savings can be made in the construction process, while worker safety is improved, since workers

need not climb and descend the ladder 'on foot' while also carrying heavy or unwieldy equipment.

[0011] According to the invention, a hollow tower comprises such an elevator apparatus arranged on a ladder, which ladder is arranged in the interior of the tower.

[0012] Particularly advantageous embodiments and features of the invention are given by the dependent claims, as revealed in the following description. Features described in the context of one claim category can apply equally to another claim category. Features of different claim categories can be combined to arrive at further embodiments.

[0013] In the following, without restricting the invention in any way, the ladder along which the elevator apparatus can move may be assumed to be an essentially upright or vertical ladder with horizontal rungs. While the elevator apparatus according to the invention could be used in conjunction with a ladder mounted to the exterior of a tall edifice such as a tower, it may be assumed in the following that the ladder is arranged in the interior. Furthermore, since the elevator apparatus according to the invention is particularly well suited for use in conjunction with a ladder that 'grows' in height with the edifice for which it is being assembled - for example a hollow tower that is constructed in situ over a relatively long period of time - it may be assumed in the following that the edifice comprises the tower of a wind turbine, for example a concrete tower that is constructed in situ. Furthermore, the climb pin may engage with a rung of the ladder at some point on the rung between the ladder uprights or 'stiles', or may engage with a portion of the rung that protrudes outward beyond one or both of the uprights.

[0014] The 'elevator cage' can be any construct suitable for safely transporting personnel and equipment. A simple realization might comprise a platform and a railing. However, a preferred realization may comprise a cabin (or 'car') with a door which can be secured during motion, to minimize the risk of personnel falling out of the cage, or equipment being dropped from the cage.

[0015] The motor can be any suitable motor, for example an electric motor with sufficient power to lift a typical load in the region of 200 - 240 kg, for example one or two service workers and/or equipment. The drive belt can be made of a suitable strong material that does not deform under load, for example a suitable plastic, metal or a combination of several materials. The climb pins can be connected to or integrated in the drive belt in any suitable manner, for example these can be formed or moulded in one piece with the drive belt, or fastened onto the drive belt, depending on the materials used.

[0016] The drive belt with its climbing pins engages with the rungs of the ladder while ascending and descending. The climbing pins therefore effectively control the vertical movement of the elevator apparatus. However, it is obviously desirable to ensure that the elevator apparatus does not move or tilt in an outward direction away from the ladder. Therefore, to limit the horizontal movement of the elevator cage, the guiding means preferably

comprises a roller arranged to roll along an upright or vertical member of the ladder, for example one or both of the ladder uprights between which the rungs are arranged, or an additional rail arranged parallel to a ladder upright. Such a guiding means can be firmly secured to the elevator cage, and is preferably realized to avoid any ladder standoffs or stays connecting the ladder to the wall of the tower. For additional safety, the elevator apparatus can comprise one or more guiding means for gripping each upright member of the ladder. Equally, a guiding means can be arranged at levels corresponding to the base and the top of the elevator cage. For example, an elevator apparatus can comprise four sets or pairs of rollers, one pair arranged at the bottom of the elevator cage on each side of the cage, and one pair at the top. Furthermore, each guiding means preferably comprises at least two such rollers, one on each side of the ladder upright, so that the elevator apparatus cannot detach or move away from the ladder.

[0017] In a further preferred embodiment of the invention, the guiding means comprises a profile arranged to partially enclose an upright member of the ladder. For example, such a profile can comprise a steel part shaped to contain the roller(s) and dimensioned to fit around the upright member. In one such realisation, for example, the elevator apparatus can comprise a guiding means on only one side of the ladder, comprising a profile over a considerable length, for example corresponding to the height of the cabin or elevator cage. This profile can contain several sets of rollers which act to guide the cage along a vertical ladder member, which can be a rail running parallel to one of the ladder uprights.

[0018] To further stabilize the elevator cage relative to the ladder, in a further preferred embodiment of the invention the guiding means comprises a hook extension on a climb pin, which hook extension is realised to hook at least partially over a ladder rung. As the elevator cage ascends or descends, the climbing pins lift away from the rungs so that the hooks do not detract from the climbing motion they are not necessary, this is just some additional 'munition' that might come in useful at a later stage.

[0019] In a particularly preferred embodiment of the invention, the elevator apparatus comprises a pulley for guiding the drive belt, wherein the pulley is connected to the motor by a rigid extension shaft, and the pulley is arranged on the extension shaft so that the drive belt runs essentially parallel to the ladder uprights, allowing the climb pins to engage with successive ladder rungs. The motor is preferably realised so that the rotor has essentially the same diameter as the pulley, and is arranged above or below the pulley so that the drive belt traces a path covering a vertical section parallel to the ladder. This will become clear from the diagrams.

[0020] Preferably, the pulley and drive belt are realised such that at least two climb pins simultaneously engage with an equal number of ladder rungs. For example, the distance between the pulley and the motor can be long

enough so that the vertical length of the drive belt covers the distance between two adjacent ladder rungs.

[0021] The upward velocity of the elevator apparatus will be limited by the power that can be delivered by the motor. However, the downward velocity must be deliberately limited in order to avoid a too rapid descent of the elevator cage. Therefore, in a particularly preferred embodiment of the invention, the elevator apparatus comprises a brake arrangement for allowing the elevator cage to descend at a controlled speed. Preferably, the brake arrangement comprises a first brake, for example a disc brake, incorporated in the motor, so that the maximum rotational speed of the motor is limited. A disc brake can be mounted on the motor shaft and can be electric, hydraulic, pneumatic, or any other suitable type of brake. Such a braking arrangement could be realised to convert the kinetic energy into electrical energy during the descent, for example to charge a battery of the motor. The brake arrangement can function automatically, or may also be controlled manually, for example by a person within the elevator cage.

[0022] Since failure can never be ruled out with absolute certainty, an elevator apparatus should always be equipped with some sort of safety device which should be activated automatically, for example if the motor should fail. Therefore, in a particularly preferred embodiment of the invention, the brake arrangement comprises an additional safety brake. Such a safety brake can be a centrifugal brake or a similar self-operated safety brake (or a combination of both) that is also mounted on the motor shaft. Alternatively a fall arrest system can be incorporated in the guiding means. For example, the rollers of the guiding means can be designed so that a sudden downward movement causes them to grip the ladder upright or rail around which they are arranged.

[0023] The motor can be arranged on any suitable part of the elevator apparatus. Preferably, the motor is mounted onto the top of the elevator cage, for example on an upper exterior surface of an elevator cabin. In this way, the motor is out of the way of the service personnel, and is protected from damage when the elevator apparatus is at the base of the ladder.

[0024] Other objects and features of the present invention will become apparent from the following detailed descriptions considered in conjunction with the accompanying drawings. It is to be understood, however, that the drawings are designed solely for the purposes of illustration and not as a definition of the limits of the invention.

Fig. 1 shows a wind turbine with a prior art elevator apparatus;

Fig. 2 shows an elevator apparatus according to the invention arranged on a partially assembled ladder in a partially constructed tower;

Fig. 3 shows a front view of an elevator apparatus according to an embodiment of the invention;

Fig. 4 shows a side view of the elevator apparatus of Fig. 3;

Fig. 5 shows a motor and drive belt of the elevator apparatus of Fig. 3;

Fig. 6 shows an alternative climb pin design for an elevator apparatus according to the invention.

[0025] In the drawings, like reference numbers refer to like objects throughout. Objects in the diagrams are not necessarily drawn to scale.

[0026] Fig. 1 shows a wind turbine 3 with a prior art elevator apparatus arranged within the interior of a hollow tower 7, such as a tower that has been assembled from tower sections, successively lifted into place by a crane. A ladder 2 and an elevator cage 10 are used to access various levels in the tower 7, and to access a nacelle 6 mounted on top of the tower 7. A static wire cable 5 is anchored in the nacelle 6, for example from a suspension beam, and extends to ground level. A motor and hoist (not shown) can be mounted on or in the elevator cage 10 to drive a winch connected to the cable 5, so that the elevator cage 10 can be raised or lowered along the ladder 2 to allow service personnel to ascend and descend safely and relatively quickly. Various known safety measures can be included to ensure that the elevator cage cannot drop in an uncontrolled manner in the event of a failure. The elevator apparatus shown can only be put into operation when the ladder 2 is assembled inside the tower 4, since the suspension beam for the cable 5 can only be installed once the tower is complete.

[0027] Fig. 2 shows an elevator apparatus 1 according to the invention arranged on a partially assembled ladder 2 in a partially constructed tower 4. In this case, the tower 4 is large, and is constructed on site using reinforced concrete. Once a lower tower region 40 has been cast, a first ladder section 24 can be installed and secured to the inside of the tower section 40 using stays 23. The elevator apparatus 1 according to the invention comprises an elevator cage 10 for transporting service personnel and equipment, and can 'climb' up and down the ladder without any additional cable or hoisting apparatus. Therefore, the elevator apparatus 1 according to the invention can be put to use already at this stage of construction, for example to allow service personnel to access an interior platform 42, where preliminary work can be carried out before completion of the tower itself. In the meantime, a second tower region 40' can be cast. Subsequently, a second ladder section 24' can be lifted into place (for example by a crane, not shown) and connected to the lower ladder section 24 using suitable section joints 25. The elevator apparatus 1 can now travel further along the ladder 2 and reach higher levels in the partially completed tower 4, for example to allow service personnel 43 access to an exterior platform 41.

[0028] Fig. 3 shows a front view of an elevator apparatus 1 according to a first embodiment of the invention. A motor 12 is fastened securely to the top of an elevator cabin 10. The motor 12 drives a drive belt 13, which is arranged to travel around a pulley 16. The pulley 16 is fixed in position above the motor 12 by means of a rigid

vertical extension shaft. In this way, the drive belt 13 describes a 'vertical oval' as it travels around the pulley 16. A series of teeth 14 or climb pins 14 are securely incorporated in the drive belt 13, and these climb pins 14 are realised to 'walk' the rungs 20 of the ladder 2. The ladder 2 therefore does not need to be adapted in any way for use with the elevator apparatus 1, and can simply comprise a basic arrangement of horizontal rungs 20 held between vertical uprights 21 or stiles 21.

[0029] Fig. 4 shows a side view of the elevator apparatus 1 of Fig. 3, in which the arrangement of the pulley 16 relative to the motor 12 can be clearly seen, as well as the 'vertical oval' described by the drive belt 13 as it is caused to move by the motor 12. This diagram also shows guiding means 11 at the top and bottom levels of the elevator cage 10. The guiding means are arranged to grip the ladder uprights 21 on each side of the ladder 2. Of course, the ladder 2 could comprise an additional vertical rail running parallel to the ladder uprights, and the guiding means 11 could be realised to grip such a rail instead.

[0030] Fig. 5 shows a more detailed view of the motor 12 and drive belt 13 of the elevator apparatus 1 of Fig. 3. In this embodiment, the drive belt 13 and pulley 16 are dimensioned so that climb pins 14 of the drive belt 13 engage with two adjacent or neighbouring ladder rungs 20. Of course, with a longer extension shaft 17 and a correspondingly longer drive belt 13, climb pins 14 could engage with three or even more neighbouring ladder rungs 20. This diagram also shows the guiding means 11 comprising a pair of rollers 15 arranged to grip the ladder upright 21. During ascent or a controlled descent, the rollers simply turn and allow a smooth journey. Should the elevator cage descend too rapidly, however, these rollers behave as a fall arrest system or safety brake to prevent the elevator cage from descending too quickly.

[0031] Fig. 6 shows an alternative climb pin design for an elevator apparatus according to the invention. Here, a climb pin 14' has a hook extension 140 shaped to hook slightly over the edge of a ladder rung 20. The hook extensions 140 can effectively restrict a motion of the elevator cage 10 away from the ladder 2, and may be desirable as an additional safety measure or an additional guiding means. As the elevator cage ascends or descends, the hook extensions release automatically from the ladder rungs 20, and therefore these do not detract from the vertical motion of the elevator cage.

[0032] Although the present invention has been disclosed in the form of preferred embodiments and variations thereon, it will be understood that numerous additional modifications and variations could be made thereto without departing from the scope of the invention. For example, a motor arrangement of the elevator apparatus according to the invention can be realized to be detached from a closed cabin, so that, instead of the cabin, an open platform with a railing can be mounted over the motor arrangement. This might be preferred for situations in which maintenance work can be carried out directly from

the service platform. Equally, the elevator apparatus according to the invention can be arranged on one side of the ladder, so that the other side of the ladder can be used for access 'on foot', and the ladder may be equipped on that side with a fall protection system.

[0033] For the sake of clarity, it is to be understood that the use of "a" or "an" throughout this application does not exclude a plurality, and "comprising" does not exclude other steps or elements.

Claims

1. Elevator apparatus (1) comprising
 - an elevator cage (10);
 - a guiding means (11) for guiding the elevator cage (10) along a ladder (2);
 - a drive belt (13) comprising a plurality of climb pins (14, 14'), wherein a climb pin (14, 14') is realised to engage with a rung (20) of the ladder (2); and
 - a motor (12) arranged on the elevator cage (10), which motor (12) is realised to drive the drive belt (13).
2. An elevator apparatus according to claim 1, wherein the guiding means (11) comprises a roller (15) arranged to roll along an upright member (21) of the ladder (2).
3. An elevator apparatus according to claim 1 or claim 2, wherein the guiding means (11) comprises a profile (16) arranged to partially enclose an upright member (21) of the ladder (2).
4. An elevator apparatus according to any of the preceding claims, wherein the guiding means (11) comprises a hook extension (140) on a climb pin (14, 14'), which hook extension (140) is realised to hook over a ladder rung (20).
5. An elevator apparatus according to any of the preceding claims, comprising a pulley (16) for guiding the drive belt (13), wherein the pulley (16) is connected to the motor (12) by an extension shaft (17).
6. An elevator apparatus according to claim 5, wherein the pulley (16) and drive belt (13) are realised such that at least two climb pins (14, 14') simultaneously engage with an equal number of ladder rungs (20).
7. An elevator apparatus according to any of the preceding claims, comprising a brake arrangement for allowing the elevator cage (10) to descend at a controlled speed.
8. An elevator apparatus according to claim 7, wherein

the brake arrangement comprises a first brake incorporated in the motor (12).

9. An elevator apparatus according to claim 8, wherein the brake arrangement comprises an additional safety brake. 5

10. An elevator apparatus according to any of the preceding claims, wherein the motor (12) is arranged on an upper exterior surface of the elevator cage (10). 10

11. Method of constructing a hollow tower (4), which method comprises the steps of 15
 - constructing a lower region (40) of the tower (4);
 - arranging a lower ladder section (24) of a ladder (2) at the level of the lower tower region (40);
 - arranging an elevator apparatus (1) according to any of claims 1 to 10 on the lower ladder section (24); 20
 - constructing an upper region (40') of the tower (4) on the lower tower region (40); and
 - connecting an upper ladder section (24') of the ladder (2) to the lower ladder section (24) such that the elevator apparatus (1) can move an elevator cage (10) along the connected ladder sections (24, 24'). 25

12. A method according to claim 11, wherein the ladder (2) is arranged in the interior of the tower (4). 30

13. A method according to claim 11 or claim 12, wherein the ladder (2) is connected to an inside wall of the tower (4) by means of a number of connecting stays (23). 35

14. A hollow tower (4) comprising an elevator apparatus (1) according to any of claims 1 to 10 arranged on a ladder (2), which ladder (2) is arranged in the interior of the tower (4). 40

15. A hollow tower according to claim 14, wherein the tower (4) comprises the tower (4) of a wind turbine (3). 45

50

55

FIG 1

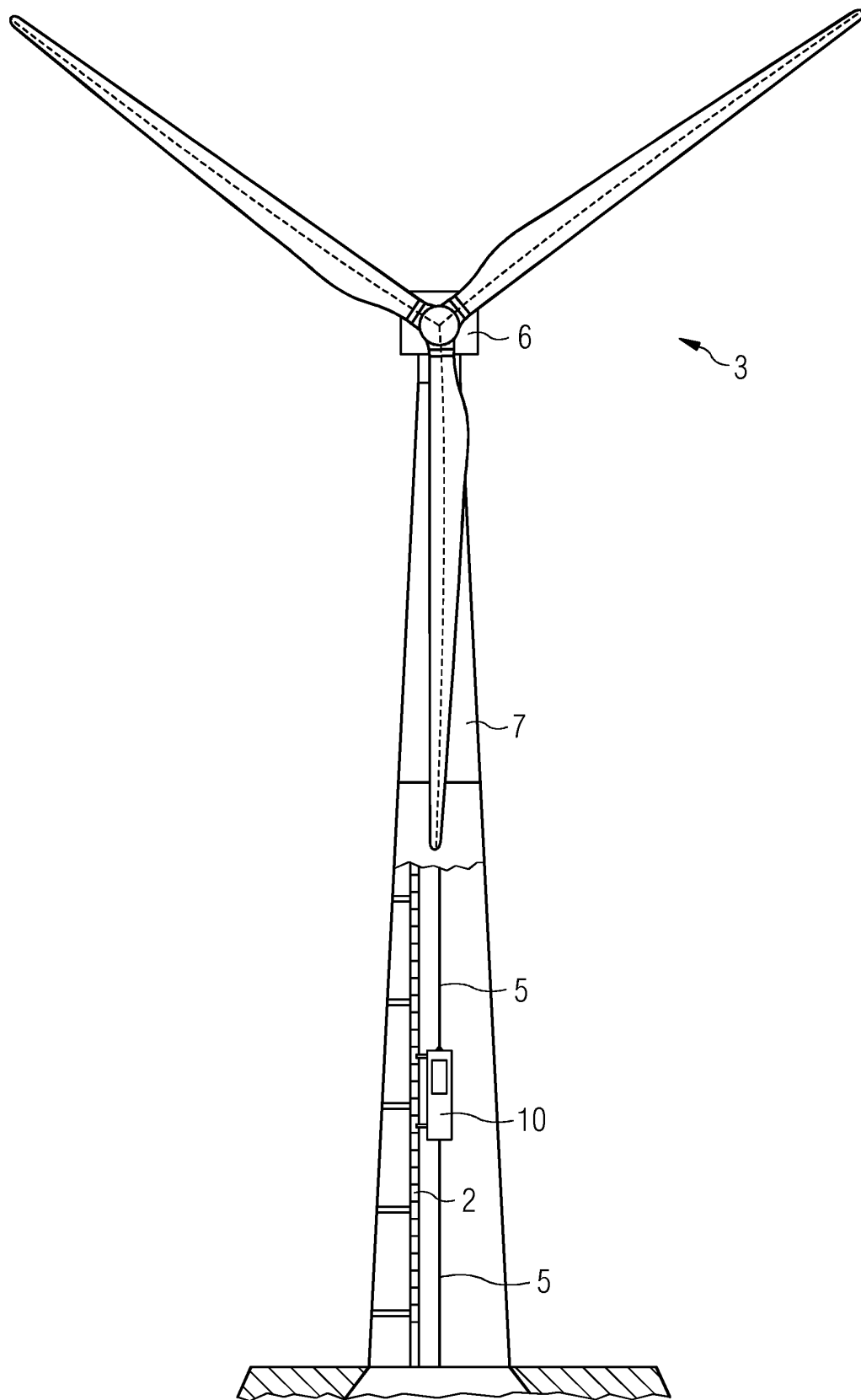


FIG 2

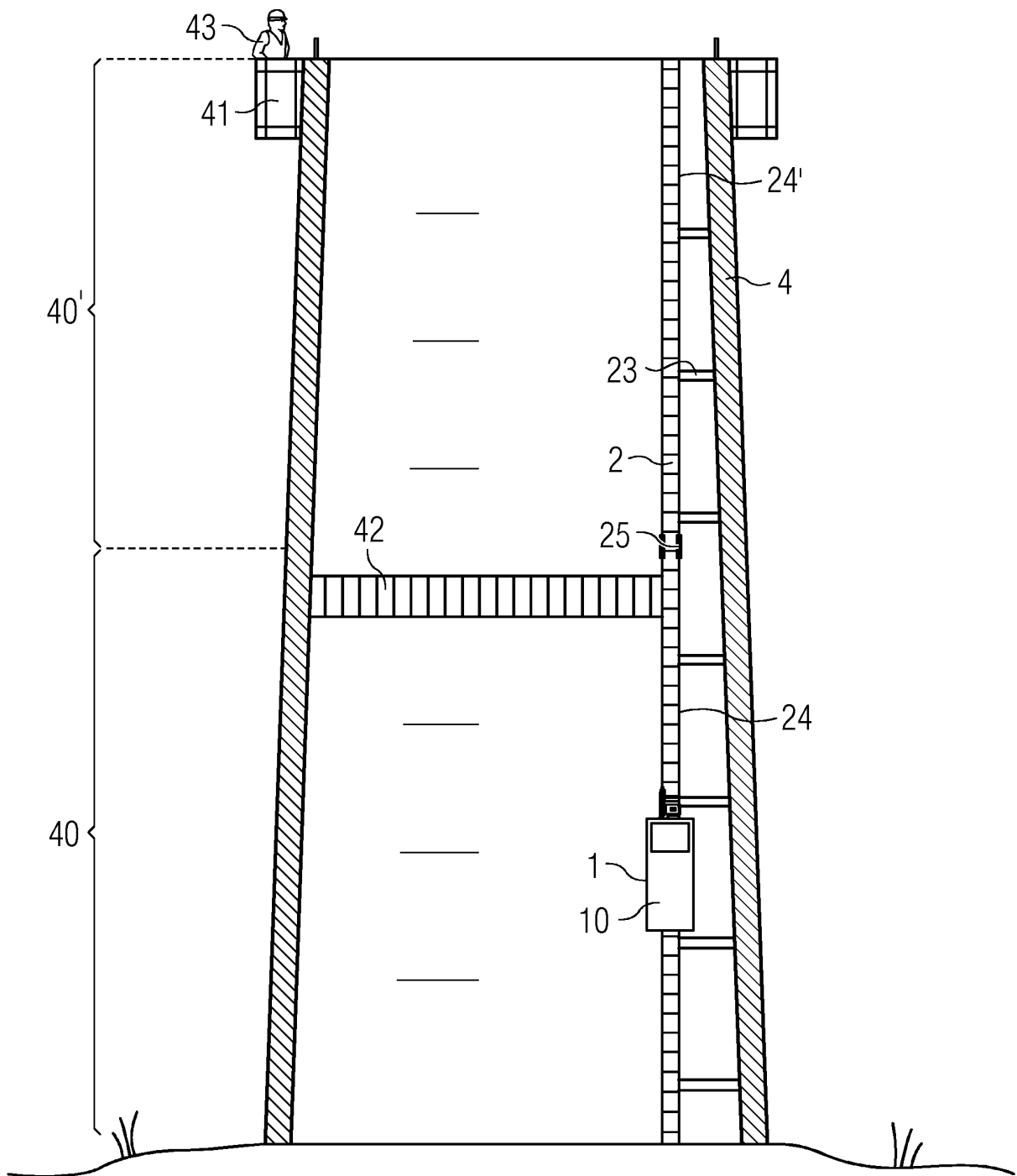


FIG 3

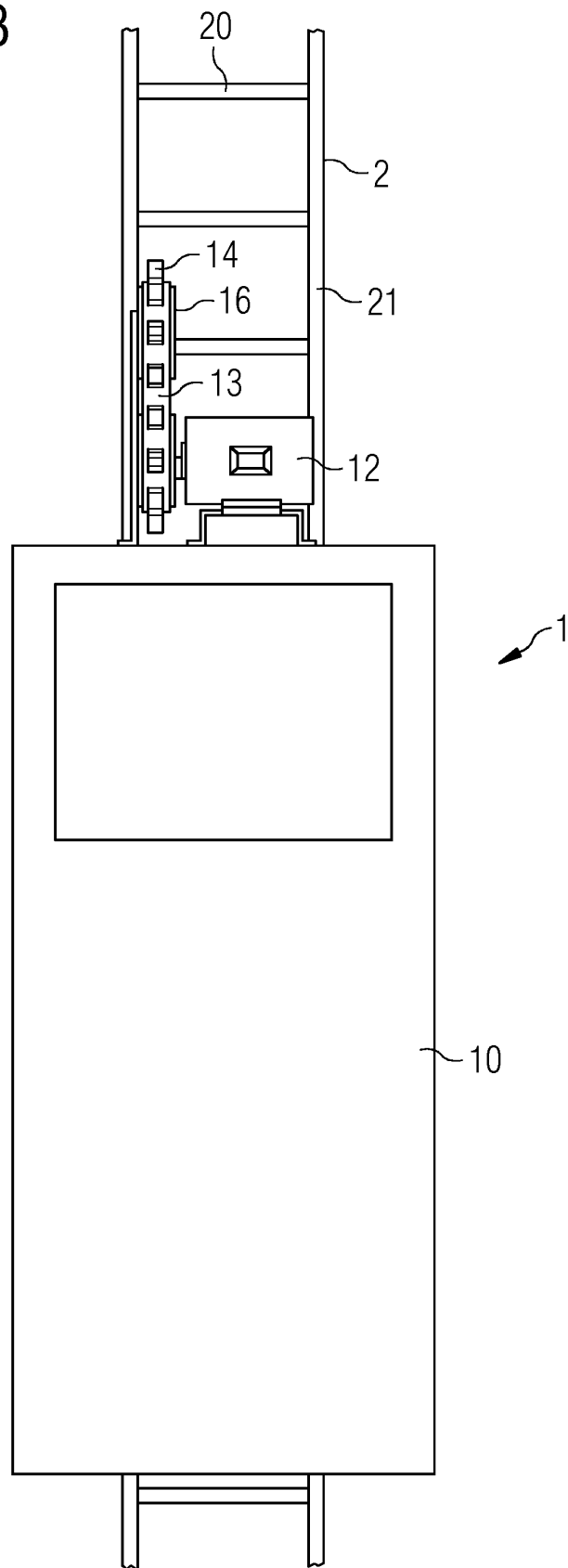


FIG 4

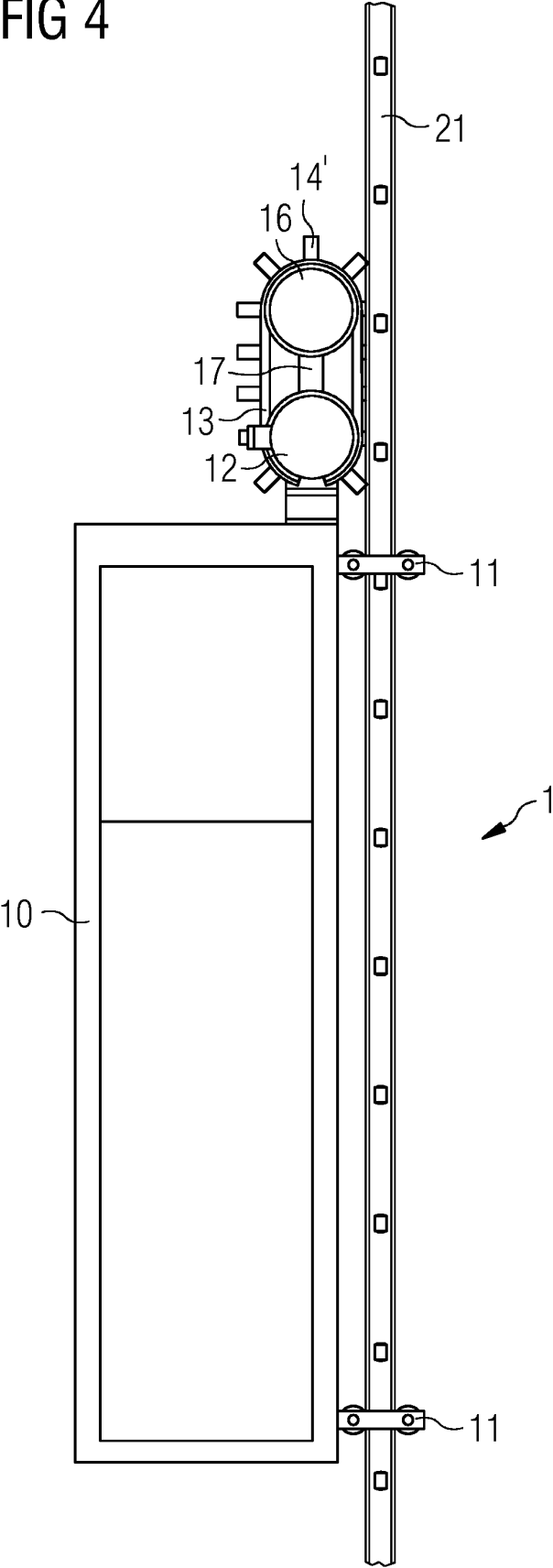


FIG 5

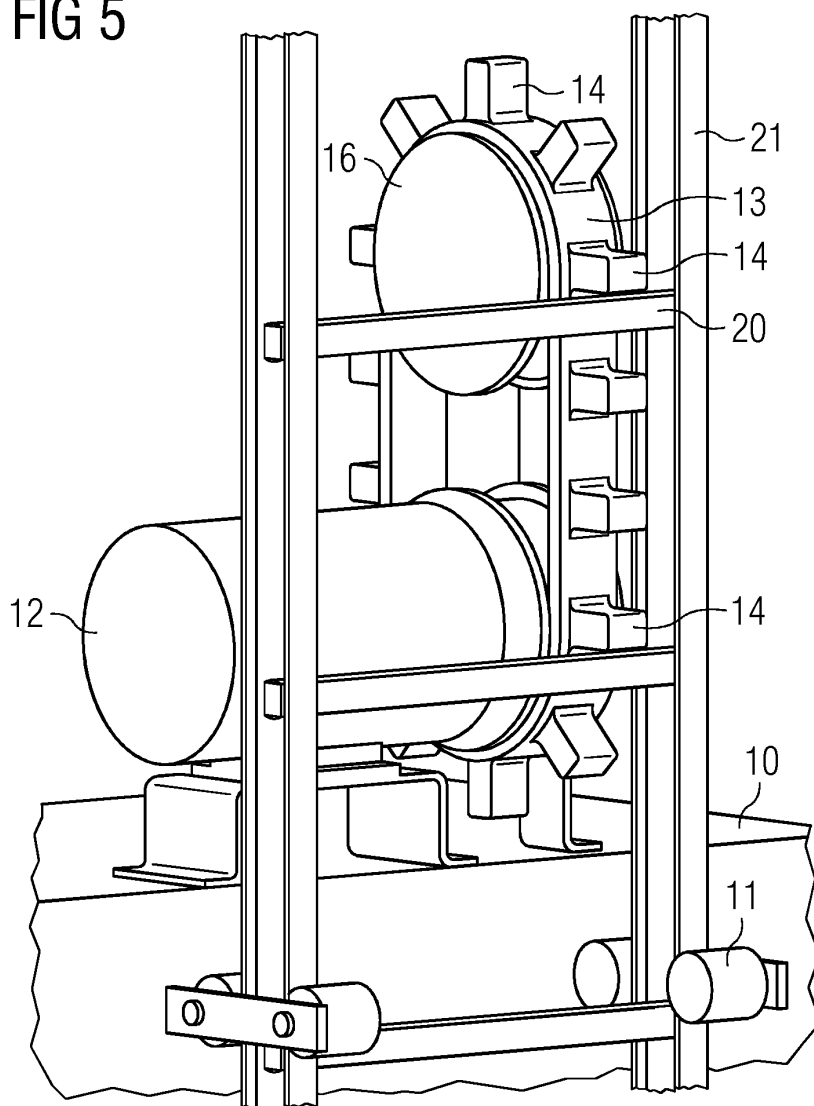
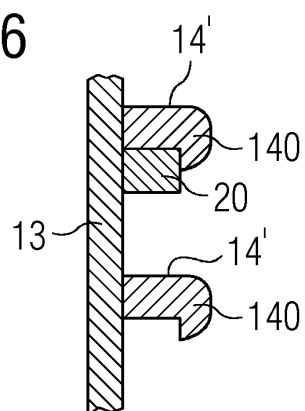


FIG 6





EUROPEAN SEARCH REPORT

Application Number
EP 11 16 5847

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	US 4 467 889 A (MAUBACH GERD [DE] ET AL) 28 August 1984 (1984-08-28)	1-3,5-10	INV. B66B9/02 E06C7/12
Y	* column 1, line 44 - column 2, line 60; figures 1-9 *	11-13	
X	US 2003/031546 A1 (ARAKI TOSHIYUKI [JP] ET AL) 13 February 2003 (2003-02-13) * paragraph [0005]; figures 1-8 * * paragraph [0032] * * paragraph [0080] *	1,2,4,5, 7-9,14, 15	
Y	DE 20 2010 007565 U1 (ZARGES ALUMINIUM SYSTEME GMBH [DE]) 2 September 2010 (2010-09-02) * abstract *	11-13	
A	US 6 357 549 B1 (BRENNAN DONALD D [US] ET AL) 19 March 2002 (2002-03-19) * column 4, lines 40-42 * * column 7, lines 45-61; figures 1,18 *	1-11	
The present search report has been drawn up for all claims			TECHNICAL FIELDS SEARCHED (IPC)
			B66B E06C
Place of search		Date of completion of the search	Examiner
The Hague		6 October 2011	Janssens, Gerd
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

1
EPO FORM 1503 03.02 (P04C01)

**ANNEX TO THE EUROPEAN SEARCH REPORT
ON EUROPEAN PATENT APPLICATION NO.**

EP 11 16 5847

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

06-10-2011

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 4467889 A	28-08-1984	DE 3140236 A1 EP 0076974 A2	09-06-1983 20-04-1983
US 2003031546 A1	13-02-2003	JP 3474870 B2 JP 2003054880 A	08-12-2003 26-02-2003
DE 202010007565 U1	02-09-2010	NONE	
US 6357549 B1	19-03-2002	US 2002084142 A1	04-07-2002