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Description

Transport device

The present invention relates to a transport device for transporting at least one rotor blade of a wind turbine. The present invention further relates to an auxiliary means for improving the transport of a rotor blade of a wind turbine. The present invention further relates to a transport arrangement which transports at least one rotor blade of a wind turbine.

Modern wind turbines often currently have a so-called horizontal axis rotor having a hub which in most cases faces the wind (windward side rotor) to which one or more, in particular three, rotor blade(s) are secured. Such a rotor blade - which will also be taken as a basis below - has a rotor blade root for direct or indirect securing to the hub. At the side facing away from the rotor blade root, the rotor blade has a rotor blade tip. In the region between the rotor blade root and the rotor blade tip, the rotor blade is constructed at least primarily in a flat manner and has two sides which can be referred to as an intake side and a pressure side. There are further provided two edges which may also be referred to as a front edge and rear edge. The front edge in accordance with provisions substantially faces the wind and is mostly constructed in a rounded manner, whereas the rear edge substantially faces away from the wind during normal operation of the wind turbine and is constructed so as to be very thin, sometimes even with sharp edges in order to achieve favourable flow separation.

Such rotor blades currently have lengths of up to 60 m and greater lengths may easily be anticipated. Lengths of from 35 to 40 m are currently very commonplace.

Reference is made at this point in general to the following documents as prior art: DE 36 04 496 A1, US 7,374,405 B2, EP 1 813 473 A2, US 6,286,435 B1 and WO 2006/000230 A1.

Reference is further made to document US 2006/0251517 A1 as prior art. This relates to a method for transporting and storing a wind turbine blade having a blade root and a blade tip. Document US 2006/0251517 A1 further relates to a bent wind turbine blade which is provided with inner ballast tanks remote from the blade root.

Where possible, such a rotor blade can be secured and transported on a special transporter, such as a flat bed trailer, on the corresponding loading face. If the length of the transporter is not sufficient, the use of a transporter having trailers can be considered. In this instance, the rotor blade with the rotor blade root thereof is secured in the region of the towing vehicle and carried and the trailer is used in the region of the rotor blade tip. During transport, the trailer is then intended to adapt in a flexible manner to movements of the rotor blade which occur. Such a trailer is in this instance coupled to the towing vehicle only by means of the transported goods - in this instance, the rotor blade.

The use of a transport vehicle having a trailer is extremely complex and also often undesirable for other reasons. In particular for transporting a rotor blade via rail, the use of a vehicle having a plurality of carriage elements which are arranged one behind the other and which are connected to each other in an articulated manner is desirable. When rail vehicles are used, consequently, a rotor blade using a plurality of rail carriage wagons which are coupled together is desirable.

Such carriage elements, in particular wagons, during travel, particularly when travelling round bends, carry out movements relative to each other which do not have to correspond to the movements of a rotor blade which is supported thereon for transport. That is to say, for transport, a rotor blade which is significantly longer than any of the carriage elements mentioned cannot be readily secured to a plurality of carriage elements at the same time. The movement of the carriage elements with respect to each other could lead to considerable tensions on the rotor blade and it could become damaged.

For this reason, the arrangement of a rotor blade can be carried out by means of special carriers, which are each arranged on a carriage element but which nonetheless allow relative movements between the secured rotor blade and the respective carriage element. Thus, the rotor blade can be arranged with the rotor blade root on a carrier on a carriage element, this carrier permitting a rotational movement between the rotor blade and the carriage element. Another carrier can carry the rotor blade in a central region on another carriage element, this second carrier permitting both a rotational movement and a translational movement relative to this carriage element. It should be noted in this instance that the carriage element on which the rotor blade root is supported and the carriage element on which the central region mentioned is supported do not have to be directly adjacent carriage elements, but instead another carriage element can be arranged between these two elements.

The rotor blade tip in this instance floats freely in space and is in principle retained only by the rotor blade itself. During the journey and depending on the peripheral conditions, in particular the route but also travel speed, the rotor blade tip will move, in comparison with a carriage element in the region of which it is located. Although it is assumed that, at least when considered in an almost stationary state, the movement of the rotor blade tip relative to the carriage element mentioned is so small that it does not leave the clear region of the carriage element, which is also referred to as the structure clearance - that is to say, the region in which all the transported goods have to be located during transport, nevertheless this cannot be ensured since, for example, potential oscillation amplitudes which should be anticipated are not precisely known.

An object of the invention was consequently to overcome the disadvantages above to the greatest possible extent, in particular to improve the transport of rotor blades of wind turbines; at least an alternative solution is intended to be proposed.

According to the invention, a blade tip damper according to claim 1 is proposed. Such a blade tip damper is provided for resiliently connecting a rotor blade of a wind turbine in the region of the rotor blade tip to a transport vehicle. This is carried out for damping oscillations of the rotor blade tip when the rotor blade is transported. The blade tip damper comprises an anchoring portion which is intended to be secured on the transport vehicle, and in particular to a carriage element of a multi-articulation transport vehicle. There is further provided a gripping portion for securing to the rotor blade in the region of the rotor blade tip. Finally, the blade tip damper also has a damping portion for producing a resilient, damped connection or connection which acts resiliently between the anchoring portion and the gripping portion. The blade tip damper is constructed in such a manner that a force transmission is carried out between the anchoring portion and the gripping portion by means of a tensile stress. The blade tip is consequently not securely connected to the anchoring portion and consequently the transport vehicle, but instead the connection is constructed freely in such a manner that in principle it applies only a tensile force and consequently a force in only one direction to the rotor blade in the region of the rotor blade tip thereof. In particular no pressing or pushing forces are intended to be transmitted to the rotor blade in this region. Transverse forces can also be transmitted only in a limited manner. Instead the blade tip damper permits a movement transversely relative to the tensile force. Of course, this does not exclude that, optionally in the region of the rotor blade tip or in the vicinity thereof, there are arranged complementary means which could transmit a pressing or pushing force.

The connection between the anchoring portion and gripping portion and consequently between the respective transport vehicle or wagon element and the rotor blade tip is constructed in a resilient manner and the force transmission is accordingly resilient. The blade tip damper consequently differs substantially from lashing since it provides for a resilient connection and additionally also has damping. Preferably, the tensile force is also applied to the rotor blade in only one direction.

Preferably, the damping portion has a resilient element and a damping means and/or a non-linear path/force behaviour. Owing to the resilient element, for example, a spring, the resilient behaviour of the connection between the anchoring portion and gripping portion can be achieved. Owing to a damping means, the damping is accordingly achieved. Preferably, the path/force behaviour of this connection is non-linear. If the rotor blade tip moves during transport relative to the anchoring portion counter to the tensile stress, the tensile stress increases with a corresponding movement of the rotor blade tip, the increase of this counter-force increasing in an excessively proportional manner with the path. This can be carried out by means of non-linear resilient behaviour or it may also be carried out abruptly, for example, by a spring being combined with a rubber element and optionally also additional elements. Thus, it is possible, for example, to first produce a counter-force by means of corresponding resilient tension until, as the path of the rotor blade movement increases - it would clearly also be possible to speak of a distance between the rotor blade tip and anchoring portion - for example, the resilient element reaches a threshold value, such as, for example, reaches the maximum compression thereof, whereupon the said rubber element then becomes active and in comparison with the resilient element has a substantially more rigid resilient action or greater spring constant.

In a further preferred manner, the damping portion has an adjustable and/or direction-dependent brake element. Such a brake element may also be understood to be a type of non-linear damping means. A brake or braking force only acts counter to a movement but without actively initiating a movement itself. Such a brake element consequently acts counter to the movement of the rotor blade tip in one direction but does not guide the rotor blade tip itself back. Preferably, the damping element, in particular the brake element described, can be adjusted in terms of its damping behaviour or braking action. This is not only intended to be proposed for an adjustment with respect to the corresponding rotor blade, but also in order to take into account the specific loading state and for other peripheral conditions, such as the provided transport path or the transport speed or prevailing winds on the day of transport.

According to an embodiment it is proposed that, in order to transmit a tensile stress, a cable and optionally at least one redirection means, in particular at least one redirection roller, is provided to redirect the cable. As a result of the use of a cable, a simple force transmission is possible and takes into account the fact that in principle only one tensile stress is intended to be transmitted. In principle, means which act in the manner of a cable, such as, for example, a chain or a wire cable or a belt, can also be used. Optionally, one or more redirection means, such as redirection rollers, are used. The transmission path for transmitting the tensile stress can thereby be lengthened. The damping means consequently does not necessarily have to have space between the anchoring portion and the rotor blade tip. In addition, by using a redirection roller, an action in the manner of a pulley block may also be achieved. It is further possible, in spite of the use of a tensile stress between the anchoring element and the rotor blade tip, to use a damping element, in particular also a resilient means, which is constructed for pressure loading.

According to yet another embodiment, it is proposed that the blade tip damper be characterised in that the gripping means is provided to be secured to two substantially flat sides of the rotor blade, in particular to the pressure side and to the intake side, in such a manner that a contact between the blade tip damper and the rear and/or front edge of the rotor blade is prevented. In this regard, a blade tip damper also differs from a simple lashing operation. It is thereby possible in particular for a thin and sensitive rear edge not to be damaged by the use of a blade tip damper.

Preferably, the blade tip damper is provided, when assembled in a state in accordance with provisions, to permit a movement of the rotor blade tip relative to the anchoring portion of at least 10 cm, in particular at least 30 cm.

The blade tip damper consequently does not generally prevent movements of the rotor blade tip, but instead permits a degree of freedom of movement which in particular corresponds to the relative movement of the rotor blade tip with respect to the relevant transport element in accordance with a consideration without oscillations.

A transport device according to claim 7 is further proposed. The transport device is provided for transporting a rotor blade of a wind turbine on a transport vehicle, having a plurality of carriage elements which are arranged one behind the other and which are connected to each other in an articulated manner, such as, for example, a plurality of goods wagons of a goods train of the railway. The transport device comprises a blade root carrier for securing on a first carriage element for carrying the rotor blade of a rotor blade root on that first carriage element.

Such a blade root carrier is according to provisions secured to the first carriage element during transport but at least arranged and secured to the rotor blade in the region of the rotor blade root. To this end, there may also be used on the rotor blade the flanges and/or other securing devices with which the rotor blade is intended to be secured to the rotor blade hub.

There is further provided for arranging and/or securing on a second carriage element a central carrier which carries the rotor blade in a central region, that is to say, between the rotor blade root and rotor blade tip and consequently in this region on the second carriage element. Both the blade root carrier and the central carrier or middle carrier can each be moved relative to the respective carriage element on which they are arranged. The possible movement may comprise a rotational movement, in particular about a perpendicular rotation axis, and a translational movement, in particular in a horizontal plane, and a combination thereof. In principle, the blade root carrier and the central carrier are provided and configured to substantially carry the rotor blade alone.

The transport device further comprises a blade tip damper for producing a resilient damped or attenuated connection between a third carriage element and the rotor blade in the region of the rotor blade tip thereof in order to damp oscillations of the rotor blade tip. The term damped or attenuated connection is intended to be understood to mean that in particular resilient relative movements which occur between the rotor blade tip and the third carriage element are damped or attenuated. The blade tip damper consequently has dissipative properties.

Preferably, a blade tip damper according to the invention is used and any functionalities will be appreciated inter alia from the above explanations relating to the above blade tip damper.

Preferably, the blade tip damper is provided to be connected to the rotor blade in the region of the rotor blade tip thereof in order to damp oscillations of the rotor blade tip, without carrying the rotor blade in this region. The blade tip damper consequently differs in terms of the function thereof substantially from the blade root carrier and the central carrier, which (at least partially) carry the rotor blade and in this instance also absorb a gravitational force of the rotor blade and transmit it to the respective carriage element. In contrast, the blade tip damper is intended to prevent excessively powerful movements of the rotor blade tip, without carrying the blade in this instance.

The blade tip damper is preferably provided to produce a tensile stress between the rotor blade and the third vehicle element and/or the blade tip damper has a resilient element for achieving a pretensioning between the rotor blade and the third vehicle element. It is thereby possible to limit the movement of the rotor blade tip during transport in a simple manner, without a supporting element being required. By using pretensioning, the rotor blade tip can already be pulled in a direction, such a direction in principle being directed transversely relative to one of the sides, in particular a pressure side or an intake side. By connecting a resilient element, such pretensioning can be achieved in a simple manner.

According to an embodiment, the blade root carrier has a counter-weight. The rotor blade in the region of the blade root thereof can thereby be arranged in an eccentric manner with respect to a centre axis of the transport vehicle which extends in the travel direction. It is thereby possible to take into account, on the one hand, the overall shape of the rotor blade and the circumstance when a centre of gravity of the rotor blade does not correspond to a geometric centre point of the rotor blade. The counter-weight is consequently provided to compensate for an eccentric arrangement of the corresponding centre of gravity. Optionally, the blade root carrier has a displacement mechanism which is provided to move the counter-weight from a first position for the transport of a rotor blade into a second position for unloaded travel without a rotor blade and vice-versa. The counter-weight can consequently be moved for unloaded travel at least closer to the longitudinal axis of the transport vehicle in a horizontal direction in order consequently also to have a favourable weight distribution even in the event of unloaded travel.

The transport device is preferably provided for transporting a rotor blade having a length of at least 25 m, in particular a length of at least 35 m. In particular, the transport device is consequently provided to transport a rotor blade of such a length that it is carried on a rail vehicle on a plurality of wagons.

Furthermore, there is proposed a transport arrangement comprising a transport device according to the invention, a multi-articulation vehicle having at least a first and a second carriage element which are connected to each other in an articulated manner, and a rotor blade of a wind turbine, which rotor blade is secured on the transport device and which is arranged on the blade root carrier on the first carriage element in the region of the rotor blade root thereof and is carried thereon, is arranged on the second carriage element in a central region on the central carrier and is carried thereon, and is resiliently connected to the second or a third carriage element in the region of the rotor blade tip thereof by means of the blade tip damper. Such an arrangement of the rotor blade on a transport arrangement is also intended to be understood to be a use of the transport device in accordance with provisions. Such a transport arrangement is in principle provided to transport the rotor blade.

Preferably, the rotor blade has a chord - in cross-section transversely relative to the rotor blade longitudinal axis a line which connects the front edge and rear edge - which is inclined with respect to the horizontal, in particular at an angle of from 30 to 60° with respect to the horizontal plane and in particular through an angle of from 40 to 50° with respect to the horizontal plane. Oscillations of the rotor blade occur substantially transversely relative to this chord, that is to say, in the direction of the two sides. If the rotor blade, that is to say, the chord is located perpendicularly, only oscillation movements - if any - occur in principle in the horizontal plane, whereas, when the rotor blade is arranged horizontally, that is to say, when the chord is horizontal, only vertical oscillation movements are to be anticipated. The inclined arrangement consequently provides a compromise between the two positions.

Explanations and descriptions which are set out for transporting a rotor blade are also - where applicable - significant for the blade tip damper, the transport device and the transport arrangement.

The invention is explained in greater detail below with reference to examples and with reference to the appended Figures, in which:
Figure 1 shows a transport arrangement according to the invention;
Figure 2 shows a transport device according to the invention on a plurality of coupled carriage elements,
Figure 3 shows a blade root carrier of a transport device according to the invention in a position for transporting a rotor blade,
Figure 4 shows a blade root carrier according to Figure 3, but in a position for unloaded travel,
Figure 5 shows a transport arrangement according to the invention having a blade root carrier in the foreground,
Figure 6 shows a central carrier according to a transport device according to the invention,
Figure 7 shows a gripping portion of a blade tip damper according to the invention,
Figure 8 is a schematic illustration of a blade tip damper according to the invention in an arrangement of a transport device in accordance with provisions,
Figure 9 shows a portion of a blade tip damper including a damping portion,
Figure 10 is a side view of a gripping portion of a blade tip damper,
Figure 11 is a sectioned view of a pressure piece arrangement of a gripping portion of Figure 10 according to the section A-A of Figure 10,
Figure 12 is another view of a gripping portion of a blade tip damper,
Figure 13 is a perspective view of a blade tip damper,
Figure 14 is a side view of a part-region of a blade tip damper,
Figure 15 is a plan view of a portion of a blade tip damper of Figure 14,

Figure 16 is a lateral sectioned view according to section A-A in Figure 15 with respect to the portion of the blade tip damper according to Figure 15,
Figure 17 is a perspective view of a redirection device of a blade tip damper,
Figure 18 is another view of a redirection device according to Figure 17,
Figure 19 shows a tensile element for use with a blade tip damper.

The same reference numerals may refer to elements which are identical or similar.

The transport arrangement 1 according to Figure 1 comprises four carriage elements 2, 4, 6 and 8 of a transport vehicle such as a goods train, whose portion is illustrated here only schematically. On the carriage elements 2, 4, 6 and 8 or in the region thereof, a rotor blade 10 is arranged and carried at that location. The rotor blade 10 is arranged in the root region 12 thereof on a blade root carrier 22 on the first carriage element 2 and is carried at that location. In the central region 16 thereof, the rotor blade 10 is arranged by means of the central carrier 26 on the second carriage element 6 and is carried at that location. Between the first and the second carriage element 2, 6 there is another carriage element 4, but it only connects the first and second carriage element 2, 6 and otherwise is in no way connected to the rotor blade 10.

The rotor blade tip 18, which has an angled rotor blade tip region is resiliently connected with damping properties to the third carriage element 8 by means of the blade tip damper 28. There is additionally arranged on the third carriage element 8 a box 20 which is only intended to indicate another transport item on the third carriage element and in this instance gives an impression of the space available for the rotor blade to be transported.

Figure 2 shows the blade root carrier 22, the central carrier 26 and the blade tip damper 28 in the same arrangement as in Figure 1, the rotor blade 10 being omitted for the sake of clarity. In the blade root carrier 22, it is further possible to see a counter-weight 24 which enables an eccentric arrangement of the rotor blade root during transport. The central carrier 26 has in addition to a receiving member 30 an additional support element 32. The blade tip damper 28 allows a gripping portion 34 and a damping portion 36 to be seen.

The blade root carrier 22 of Figure 3 is arranged on a turntable 38. In order to receive a rotor blade root which is secured in a frame, there is provided the blade root receiving member 40, on which anti-slip mats 42 are arranged. The securing of the blade root carrier 22 on the turntable 38 is carried out by means of a large number of threaded bolts.

The counter-weight 24 is substantially arranged on the blade root receiving member 40 in order to enable the eccentric support of the blade root. It should be taken into account that the perspective of Figures 3 and 4 is directed counter to the perspective of Figures 1 and 2.

In order, after a rotor blade is unloaded, to enable subsequent unloaded travel without any rotor blade, the counter-weight 24 can be moved from the position shown in Figure 3 to the position shown in Figure 4. To this end, a hand wheel 44 is used for this transverse adjustment of the counter-weight. The hand wheel activates a spindle and can consequently achieve the displacement of the counter-weight 24 on the blade root receiving member 40. For fixing in the first position for the transport, a first arresting member 46 is provided and, for fixing in the second position for the unloaded travel, the second arresting member 48 is provided. The arresting members 46, 48 prevent the counter-weight 24 both from being displaced and from tilting out of the blade root receiving member 40. There is further provided another stop 50, which limits the displacement of the counter-weight towards the centre position.

Figure 5 shows a transport arrangement 1 in a view towards the root region 12 of the rotor blade 10. The root region 12 is secured in a frame 52. This frame can also be used for the transport of the rotor blade 10 on other transport vehicles. The frame 52 rests on the blade root receiving member 40 of the blade root carrier 22 and is lashed thereto by means of lashing straps 54. The turntable 38 allows substantially the centre of the first carriage element 2 to be seen. The counter-weight 24 is accordingly arranged in the transport position thereof.

The central carrier 26 according to Figure 6 has a central carrier receiving member 30 which is arranged on a sliding turntable 56. The central carrier receiving member 30 is provided with anti-slip mats and has centering elements 58.

There is further provided a frond support 60 which is securely connected to the central carrier receiving member 30 by means of connection carriers 62. The frond support 60 has counter-weights 64 and is located so as to be able to be displaced in another region of the second carriage element. The frond support 60 has two pressing plates 66 in order to securely clamp therebetween the rotor blade to be transported and in particular to prevent powerful movements of the rotor blade. It can be seen that the pressing plates 66 are positioned in an oblique manner according to Figure 6 since the rotor blade which is intended to be transported is also intended to be received in a correspondingly obliquely positioned manner. Using clamping screws 68, the rotor blade can be securely received between the pressing plates 66.

The pressing plates 66 are pivotably secured to a transverse carrier 116 by means of support arms 114. The clamping screws 68 can also be released in order to fold away the support arms 114 in order to insert the rotor blade. The transverse carrier 116 terminates in any case at a transverse carrier end 118 directly beside an articulated arm member 120 in order where possible not to exceed the structure clearance during transport.

Figure 7 shows the gripping portion 34 of a blade tip damper. The gripping portion 34 has a first and a second strut 70, 72 which are movably connected to each other by means of an articulation 74. The first strut 70 has a pressing plate 76 and the second strut 72 has four pressing pieces 78. The rotor blade in the region of the rotor blade tip is accordingly intended to be received between the pressing plate 76 and the pressing pieces 78. For tightening, a tension rod 80 is provided together with a coupling nut 82. Using the catch 84, the gripping portion 34 can be opened in the region of the tension rod 80 in order to be able to better position it on a rotor blade. On the securing ring 86, it is then possible to secure a tensile connection such as a cable for connection to a damping portion.

Figure 8 is a schematic side view of a blade tip damper 28, a portion of the rotor blade 10 and the third carriage element 8 being illustrated in cross-section. The gripping portion 34 is secured to the rotor blade 10. The rotor blade 10 in this instance is securely received between the pressing plate 76 and pressing pieces 78. The coupling nut 82 of the tension rod 80 is tightened securely. It can be seen that the gripping portion 34 prevents any contact with respect to the rotor blade front edge 88. The securing is carried out exclusively by means of the intake side 92 and the pressure side 94. It can further be seen that the rotor blade 10 is located with the chord 96 thereof oblique with respect to the third carriage element and consequently the horizontal.

A cable 100 is secured to the securing member 86 of the gripping portion 34 by means of a hook 98. The cable 100 is guided via a first redirection roller 102 to a second redirection roller 104 and finally to a cable securing member 106. The redirection roller 104 is connected to a movable piston 108 which leads into a resilient damping unit 110. The resilient damping unit has both a resilient element and a damping element, to which the piston 108 is connected. The resilient damping unit 110 with the piston 108 can be understood to be a damping portion 109.

The resilient damping element 110 is securely fixed to the third carriage element by means of a securing device 112 which can also be referred to as an anchoring portion 112. The first redirection roller 102 is also securely connected to the securing device 112 and consequently, when arranged in accordance with provisions, also securely to the third carriage element 8.

The piston 108 is pressed counter to a resilient force of the resilient damping unit 110 slightly therein. A tensile force is thereby applied via the cable 100 to the securing member 86 and consequently the gripping portion 34 and consequently via the pressing plate 78 to the rotor blade tip. In this regard, the blade tip damper is pretensioned in the illustrated arrangement.

If the rotor blade 10 now carries out in the region of the rotor blade tip thereof a pivoting movement in the direction towards the first redirection roller 102, this enables the piston 108 to move further out of the resilient damping unit 110. If the rotor blade tip now moves back again, that is to say, away from the first redirection roller 102, it must carry this out counter to the damping action of the resilient damping unit, whereby oscillations are already prevented as they begin.

During transport, the rotor blade is intended to be arranged in such a manner that - when transported by rail or railway - it fits within the "structure clearance" predetermined by the railway, that is to say that it is located where no obstacles may be constructed beside/over the rails. This also corresponds to a conventional problem with bulky goods which exceed the normal loading size of the track. In particular the tip point - as long as a modern rotor blade having an angled rotor blade tip, the tip point, is used - faces upwards in an oblique manner. The blade cross-section shortly before the tip point is located approximately over the carriage centre, that is to say, over a central longitudinal carriage axis and consequently in principle over the centre between the platforms. It is thereby intended that, in the event of the blade oscillating, there is at most the risk that at one side the structure clearance may be exceeded. In addition, a fixed/loose support on a turntable (with the blade root carrier) and a sliding turntable (with the central carrier) is used. Such a requirement can exist with loads which are located on more than one carriage in order to compensate for length changes when travelling round bends and in the event of accelerations or braking owing to the resilient buffer. It is possible to obtain a continuous "transport chain" by the rotor blade being transported on a frame via lorry, rail and/or ship from the factory to the construction site. The rail carriages are provided with adapters for these frames, that is to say, with the blade root carrier and the central carrier. On the frame - or frames since for a rotor blade in any case two frames which are in principle independent of each other are used - for easy handling, including lifting and lashing, there are container corners. In addition, stacking ability is enabled which can be used both for storage and for sea transport or inland water transport.

According to the invention, there is provided a blade tip damper which can also be referred to as a tip damper. This is intended to ensure that the tip point is not redirected to an excessive extent out of the carriage centre axis. The tip damper is configured in such a manner that it provides for a gradual build-up of a restoring force. In addition, the behaviour thereof is in any case non-linear in one embodiment by a resilient action first being achieved by means of a spring. In the event of further redirection amplitude, a rubber buffer is reached, in particular by a corresponding piston and, in the event of even greater redirection, a metal stop is finally reached. Nonetheless, the tip damper is preferably configured in such a manner that it does, however, permit redirection on bends to a degree. In principle, the tip damper of a preferred embodiment acts at one side since the rotor blade is only pulled in the region of the rotor blade tip. Owing to the selected blade position, in particular the oblique arrangement and the advantageous arrangement in the structure clearance, a single-sided action has been found to be sufficient. The force transmission from the resilient damping element or the resilient damping unit is carried out by means of a cable. An oscillating construction is prevented by means of damping, there preferably being used hydrodynamic dampers which act in one direction by the redirection of the blade from the centre position in one direction being damped, but the restoring action not being damped, since the cable used transmits only tensile forces. Furthermore, friction has a damping action.

A cable transmission is preferably used in order to advantageously use the structural space available. Owing to transmission between the cable and a piston of the damping portion, a 1:2 transmission is produced, the blade path corresponding to twice the damper path or twice the resilient path.

In order to rapidly secure the blade tip damper to the rotor blade, there is produced a gripping portion which can be arranged by means of folding shut a curved member and closing a clamping nut, whereupon the cable can be engaged, for which it is possible to use, for example, a small crane hook. The introduction of force into the blade is carried out as a pressure force, in particular via a pressure plate. The sensitive edge is in this instance completely relieved and the cable is arranged in such a manner that few force components are present on the profile edge. The action of the tip damper can already develop from approximately 100 mm of redirection of the blade tip in a direction, in particular the non-critical direction.

An arrangement of the transport device is carried out, for example, on a carriage assembly having four low-loading carriages Uiks 635 with a turntable and a sliding turntable which are available from the company HCS (Heavy Cargo Systems). For transport of three rotor blades together, ten low-loading carriages may be sufficient.

The resilient damping unit 110 is according to Figure 9 secured to a damping carrier 122 which forms part of the anchoring portion 112 which in principle completely bridges the third carriage element 8 and is secured thereto with a wide securing device 112a and a narrow securing device 112b. A cable which is not shown in Figure 9 would have to be guided over the first redirection roller 102 and over the second redirection roller 104 and secured to the cable securing member 106. The second redirection roller 104 is secured to the piston 108 and can accordingly push it into the resilient damping unit 110. In order to adjust the damping or braking action of the damping portion 108, 110, an adjustment element 124 which can also be referred to as a brake can be rotated about its own longitudinal axis.

In the tip damper there is consequently installed a hydraulic brake which, when the tip damper is pushed together, that is to say, when the piston 108 is pushed into the resilient damping unit 110, which corresponds to a pulling action on the cable, brakes and, when moving apart, when the cable is released, applies no force. The braking force is intended to be adjusted once during installation. To this end, the cable is intended to be relaxed and the piston 108, which can also be called a damper pipe, on the second redirection roller 104 which can also be called a redirection head, is intended to be pulled out as far as the stop. A securing screw

126 with a corresponding support 128 of the hydraulic brake 124 is intended to be disassembled and a housing pipe of the brake 124 according to Figure 9 is intended to be pulled out to the right as far the stop.

The housing pipe is intended, under constant tension to the right (according to Figure 9), to first be rotated around to the left as far as the stop. The brake must now allow itself to be pushed together with little force. Subsequently, the brake is intended, under constant pressure in an outward direction, to be rotated to the right, for example, through two revolutions. Finally, the support 128 and the securing screw 126 are intended to be assembled again.

The same reference numerals in the present description may refer to elements which are the same, but also similar and non-identical. It should be noted that Figures - such as, for example, Figures 13 to 16 - may illustrate different perspectives of an element, the scale between these Figures further being able to vary. That is to say, one and the same element in a Figure may appear larger or smaller than in another Figure.

The gripping portion 34 in Figure 10 is illustrated as a side view similar to the perspective view according to Figure 7. In order to describe the individual elements, reference is also made to the description of Figure 7 above. In addition, reference is made to the pressure piece arrangement 279 which has a pivot frame 280 which carries two pressure stamps 282 for pressing against a rotor blade in accordance with provisions. The pressure piece arrangement is secured to the second strut 72 so as to be able to be pivoted about a rotation axis 284. In Figure 10, a line of section A-A is indicated through the pressure piece arrangement 279 and a corresponding part-sectioned view is illustrated in Figure 11. From this, it is possible to see in particular the construction of the pivot frame 280 and the receiving of two pressure stamps 282.

Figure 12 shows another view of the gripping portion 34, which in particular clarifies the size of the pressing plate 76. It should be noted that the blade tip damper substantially or exclusively applies a tensile stress to a rotor blade when the blade tip damper is used in accordance with provisions. This tensile stress is applied via the securing member 86 to the gripping portion 34 and transmitted to the rotor blade by means of the pressing plate 76. Owing to the wide construction of the pressing plate 76, damage to the rotor blade is prevented. The pressure pieces 78 are substantially intended to actually secure the gripping portion to a rotor blade.

Figure 13 is a perspective view of a blade tip damper in a position in accordance with provisions, that is to say, a position in which the gripping portion 34 is secured to a rotor blade which is intended to be transported. For greater clarity, however, the rotor blade is not illustrated and nor is the transport vehicle, to which the anchoring portion 122 is secured in accordance with provisions. In addition, in Figure 13, the illustration of a cable for connecting the gripping portion 34 to the damping portion 109 has also been dispensed with.

The perspective illustration according to Figure 13 illustrates the arrangement of the wide securing device 112a relative to the narrow securing device 112b, which are connected by means of the damping carrier 122. The two securing devices 112a and 112b are secured at both sides to a support plate or the like of a transport device. In particular, the wide securing device 112a also prevents rotation of the secured arrangement.

The damping portion 109 is secured to the damping carrier 122. This substantially has a piston 108 which is received in a resilient damping unit 110 and which can in principle be pushed therein. The piston 108 has a second redirection roller 104. From the cable securing member 106, in accordance with provisions a cable is guided over the second redirection roller 104 and over the first redirection roller 102 to the securing member 86 of the gripping portion 34. A force direction of the piston 108 out of the resilient damping unit 110 consequently leads to a tensile loading on the securing member 86 of the gripping portion 34.

Figure 14 is a side view of the damping portion 109, which corresponds to the travel direction or counter-travel direction of transport in accordance with provisions. In particular, the behaviour of the cable securing member 106, the second redirection roller 104 and the first redirection roller 102 is illustrated.

Figure 15 is a plan view relating to the damping portion 109 which in particular clarifies an arrangement of the piston 108 and the resilient damping unit 110 parallel with the damping carrier 122. Figure 15 indicates a line of section A-A and Figure 16 is a lateral sectioned view in accordance with that line of section A-A of Figure 15.

It is possible to see from the sectioned view of Figure 16 a helical spring 202 which is constructed in the piston 108 and the resilient damping unit 110. In addition, a damper having a cylinder 204 and a piston rod 206 is provided. This damper may, for example, be constructed as a gas pressure damper or as a hydraulic damper or hydraulic brake or in a another suitable manner. The piston 108 is further provided in the region of the resilient damping unit 110 with a stop ring 208. When the piston 108 is pushed to a great extent into the resilient damping unit 110, the stop ring 208 reaches a rubber-coated stop ring 210. If the stop ring 208 reaches the stop ring 210, the piston movement is very powerfully braked, in principle in an abrupt manner, and consequently a maximum deflection of the rotor blade in the region of the gripping portion 34 which is secured thereto is predetermined. In addition, a non-linear effect is produced by this non-uniform movement, which counteracts a harmonious oscillation, in particular does not permit it or permits it with limited amplitude.

Figure 17 shows a variation of the first redirection roller 102 of Figures 13 to 16. This first redirection roller 102 is arranged between two support plates 220. The first redirection roller 102 is thereby advantageously guided and in particular the cable is prevented from springing down from the first redirection roller 102. In order to protect the cable which is guided therein but which is not illustrated in Figure 17 or in Figure 18, there are provided two round profiles 222 which are intended to ensure that the cable, even in unusual operating states, cannot travel over any sharp edges of the support plates 220 which can also be called sheet metal walls, at the right-hand side or left-hand side of the first redirection roller 102.

Such unusual operating states could potentially occur in the event of powerful braking or when buffers are deflected, the gripping portion 34 and with it the corresponding rotor blade portion, in particular the rotor blade tip, moving in principle in the travel direction and consequently transversely relative to the support plates 220. In addition, guiding of the cable and prevention of the cable from springing out can be improved.

The round profiles may comprise abrasion-resistant material. For example, they may comprise metal and be welded for durable securing.

Figure 18 shows another perspective of the support plates 220 and the round profiles 222 which are arranged thereon. The perspective of Figure 18 substantially corresponds to a viewing direction of a gripping portion 34 which is arranged on a rotor blade which is provided for transport in accordance with provisions.

Figure 19 shows a cable portion 230, which has a hook 232 for securing to a corresponding gripping portion. The cable portion 230 has a covering 234. This may serve, on the one hand, to protect the cable or cable portion 230 and vice versa to protect the elements, including the rotor blade, which the cable portion 230 could strike during transport in accordance with provisions.

Patentkrav

1. Vingespidsdæmper (28) til elastisk at forbinde en rotorvinge (10) af et vindenergianlæg i området ved dens rotorvingespids (18) med et transportkøretøj til dæmpning af svingninger af rotorvingespidsen (18) ved transport af rotorvingen (10), hvilken vingespidsdæmper (28) omfatter:
- et forankringsafsnit (122) til fastgørelse på transportkøretøjet,
- et gribeafsnit (34) til fastgørelse på rotorvingen (10) i rotorvingespidsens (18) område og
- et dæmpningsafsnit (109) til tilvejebringelse af en elastisk, dæmpet forbindelse mellem forankringsafsnittet (112) og gribeafsnittet (34), hvor en kraftoverføring mellem forankringsafsnittet og gribeafsnittet kun sker via en trækspænding.

2. Vingespidsdæmper (28) ifølge krav 1, **kendetegnet ved, at** dæmpningsafsnittet (109) har et fjederelement og et dæmpningsmiddel og/eller en ikkelineær vej-kraft-adfærd.

3. Vingespidsdæmper (28) ifølge krav 1 eller 2, **kendetegnet ved, at** dæmpningsafsnittet (109) omfatter et indstilleligt og/eller retningsafhængigt bremseelement.

4. Vingespidsdæmper (28) ifølge et af de foregående krav, **kendetegnet ved, at** der til overføring af en trækspænding er tilvejebragt et kabel (100) og eventuelt mindst et omdirigeringsmiddel, især mindst en omdirigeringsrulle (70, 72) til omdirigering af kablet (100).

5. Vingespidsdæmper (28) ifølge et af de foregående krav, **kendetegnet ved, at** gribemidlet (34) er indrettet til at blive fastgjort på to i det væsentlige flade sider af rotorvingen (10) på en sådan måde, at kontakt mellem vingespidsdæmperen (28) og rotorvingens (10) bag- og/eller forkant undgås.

6. Vingespidsdæmper (28) ifølge et af de foregående krav, **kendetegnet ved, at** vingespidsdæmperen (28) er indrettet til i tilsigtet monteret tilstand at tillade en bevægelse af rotorvingespidsen (18) i forhold til forankringsafsnittet (112) på mindst 10 cm, især mindst 30 cm.

7. Transportindretning til transport af en rotorvinge (10) af et vindenergianlæg på et transportkøretøj, med flere efter hinanden anbragte og med hinanden ledforbundne vognelementer (2, 4, 6, 8), omfattende:
- en vingerodsbærer (22) til fastgørelse på et første vognelement (2) til at bære rotorvingen (10) i området ved dens rotorvingerod (12) på det første vognelement (2),
- en midterbærer (26) til fastgørelse på et andet vognelement (6) til at bære rotorvingen (10) i et midterområde af rotorvingen (10) på det andet vognelement (6) og
- en vingespidsdæmper (28) til tilvejebringelse af en elastisk forbindelse mellem et tredje vognelement (8) og rotorvingen (10) i området ved dens rotorvingespids (18) til dæmpning af svingninger af rotorvingespidsen (18).

8. Transportindretning ifølge krav 7, **kendetegnet ved, at** vingespidsdæmperen (28) er indrettet til at blive forbundet med rotorvingen (10) i området ved dens rotorvingespids (18) for at dæmpe svingninger af rotorvingespidsen (28) uden at bære rotorvingen (10) i dette område.

9. Transportindretning ifølge krav 7 eller 8, **kendetegnet ved, at** vingespidsdæmperen (28) er indrettet til opbygge en trækspænding mellem rotorvingen (10) og det tredje køretøjselement (8), og/eller at vingespidsdæmperen (28) har et fjederelement til opnåelse af en forspænding mellem rotorvingen (10) og det tredje køretøjselement (8).

10. Transportindretning ifølge et af kravene 7 til 9, **kendetegnet ved, at** vingerodsbæreren (22) har en modvægt (24), således at rotorvingen (10) kan anbringes uden for midten i området ved dens vingerod (12) i forhold til en midterakse af transportkøretøjet, og at vingerodsbæreren (22) eventuelt har en forskydningsmekanik, der er indrettet til at bevæge modvægten (24) fra en første position til transport af en rotorvinge (10) til en anden position til tomkørsel uden rotorvinge (10) og omvendt.

11. Transportindretning ifølge et af kravene 7 til 10, **kendetegnet ved, at** transportindretningen er indrettet til transport af en rotorvinge (10) med en længde på mindst 25 m, især mindst 35 m.

12. Transportindretning ifølge et af kravene 7 til 11, **kendetegnet ved, at** der anvendes en vingespidsdæmper (28) ifølge et af kravene 1 - 7.

13. Transportanordning (1), omfattende en transportindretning ifølge et af kravene 7 til 12, et flerleddet køretøj med mindst et første og andet vognelement (2, 6), der er ledforbundet med hinanden, og en rotorvinge af et vindenergianlæg (10), der er fastgjort på transportindretningen, hvor rotorvingen (10)

- i området ved dens rotorvingerod (12) er fastgjort på vingerodsbæreren (22) på det første vognelement (2) og bæres derpå,
- i et midterområde (16) er fastgjort på midterbæreren (26) på det andet vognelement (6) og bæres derpå, og
- i området ved dens rotorvingespids (18) er elastisk forbundet med det andet eller et tredje vognelement (6, 8) ved hjælp af vingespidsdæmperen (28).

14. Transportanordning (1) ifølge krav 13, **kendetegnet ved, at** rotorvingen (10) har en afvinklet vingespids (18), der peger skråt opad.

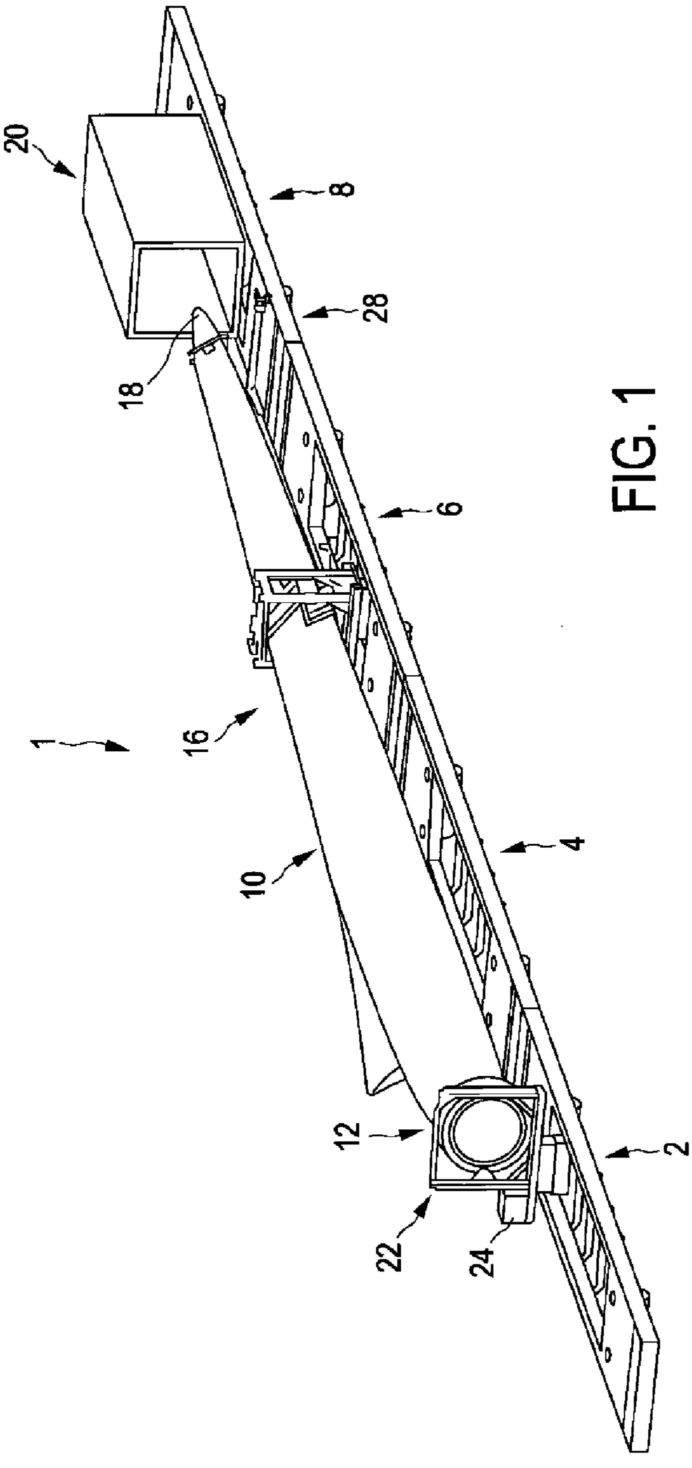


FIG. 1

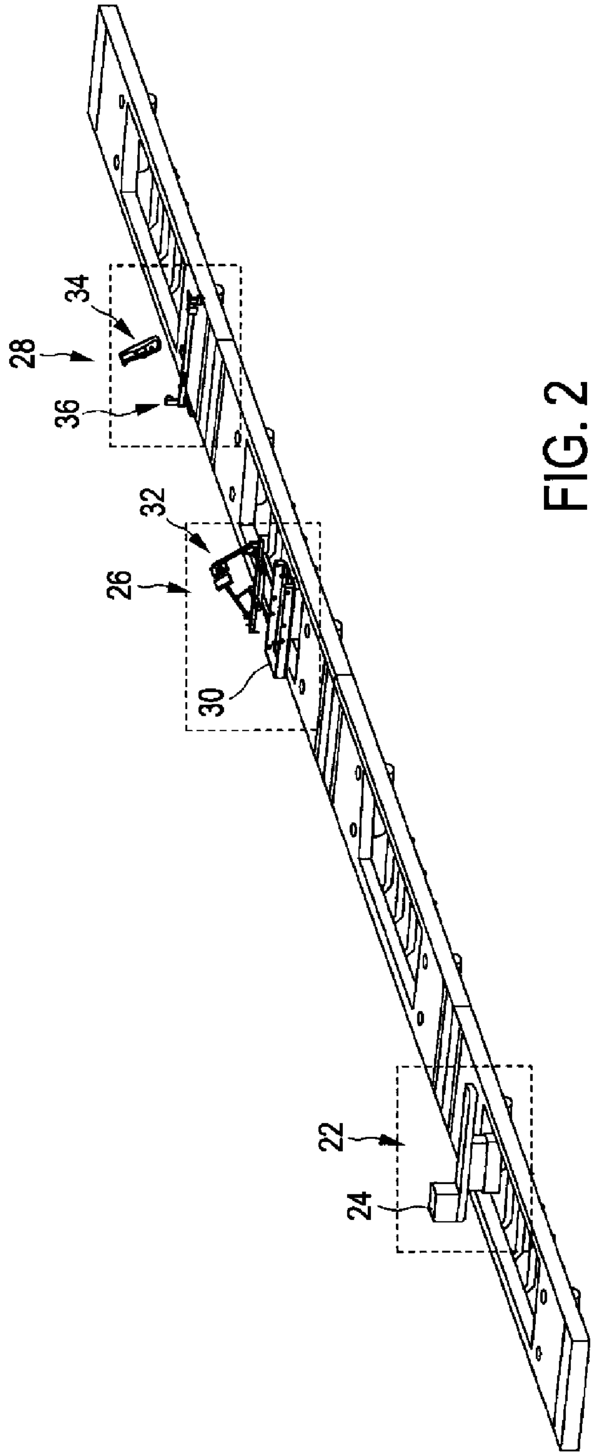


FIG. 2

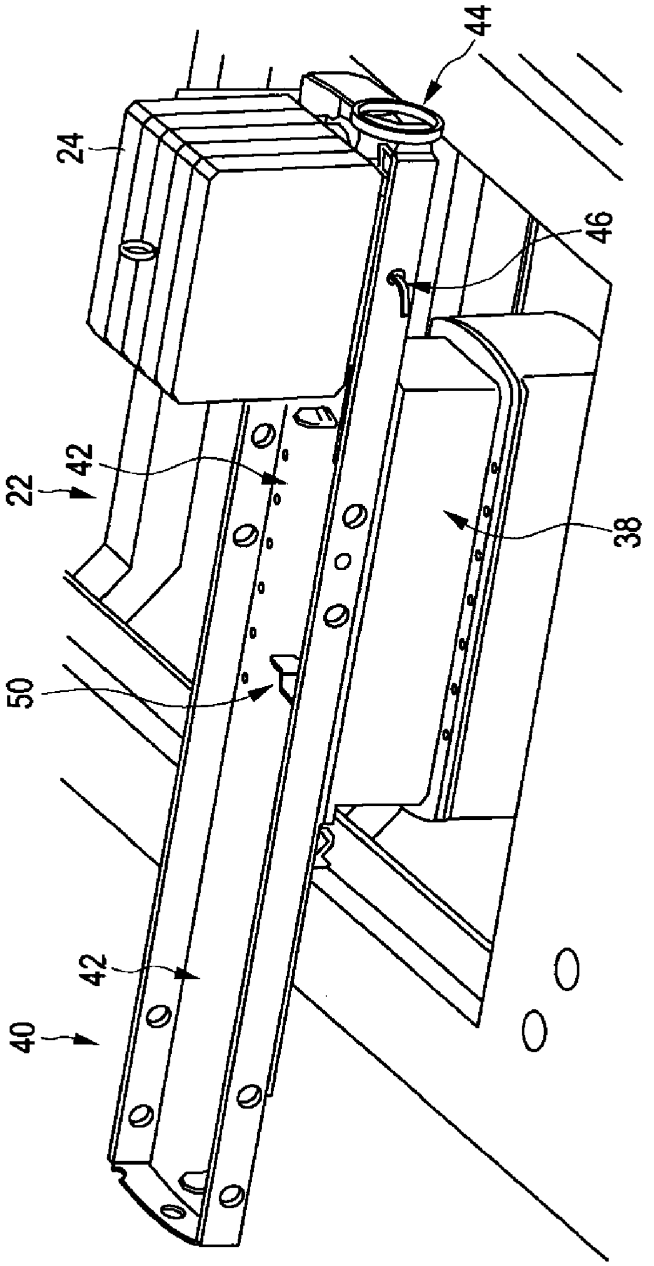


FIG. 3

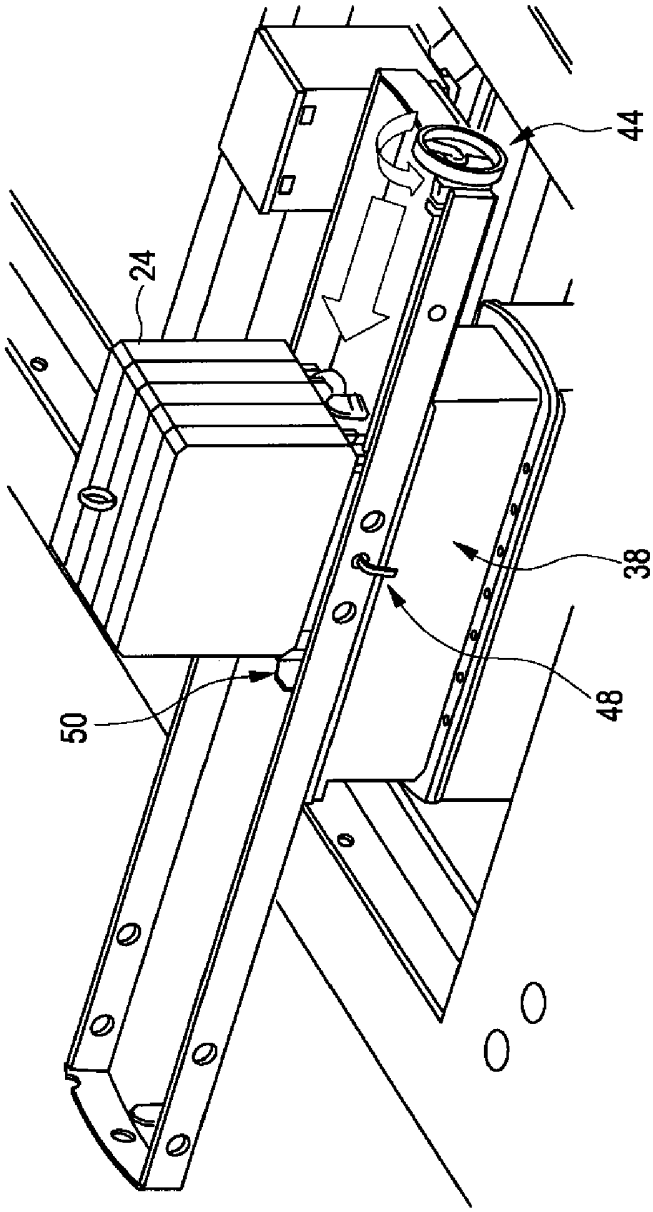


FIG. 4

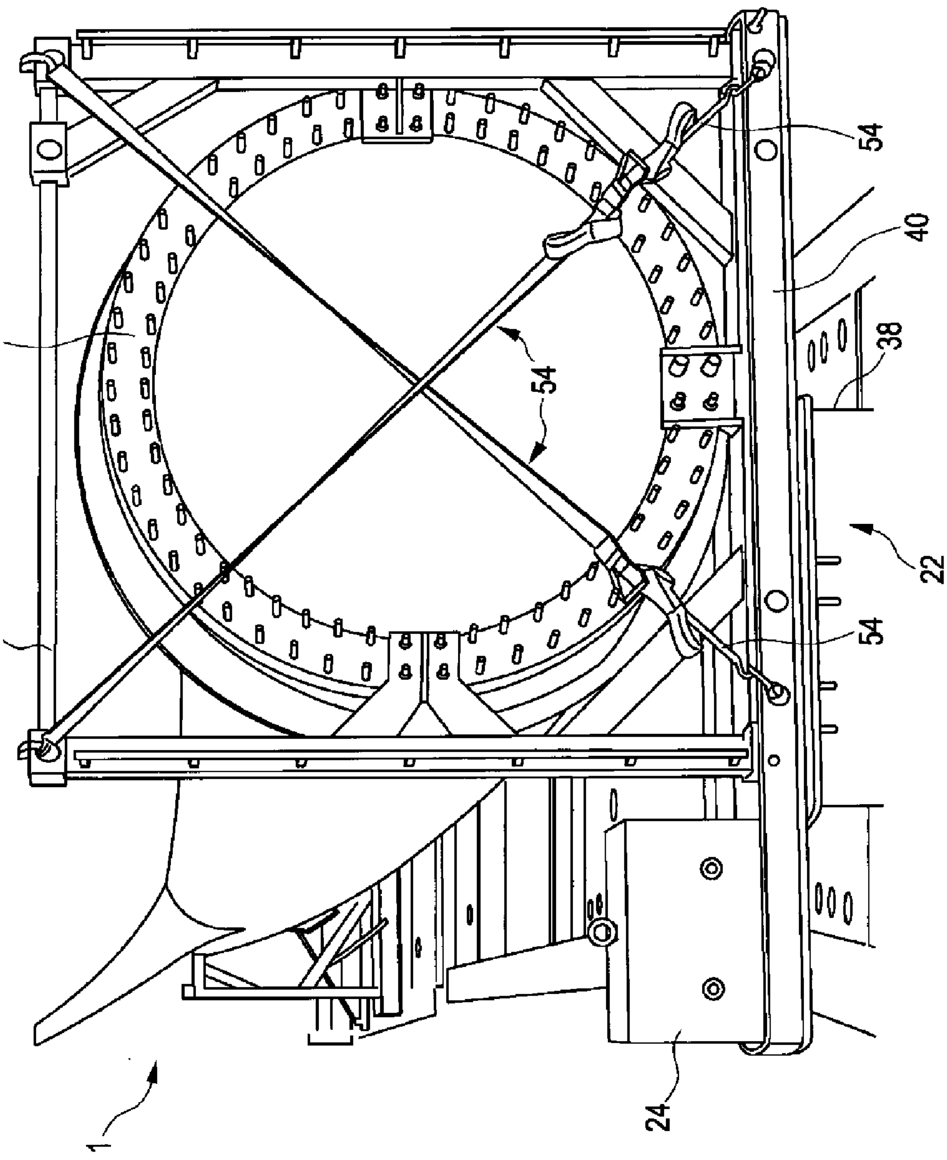


FIG. 5

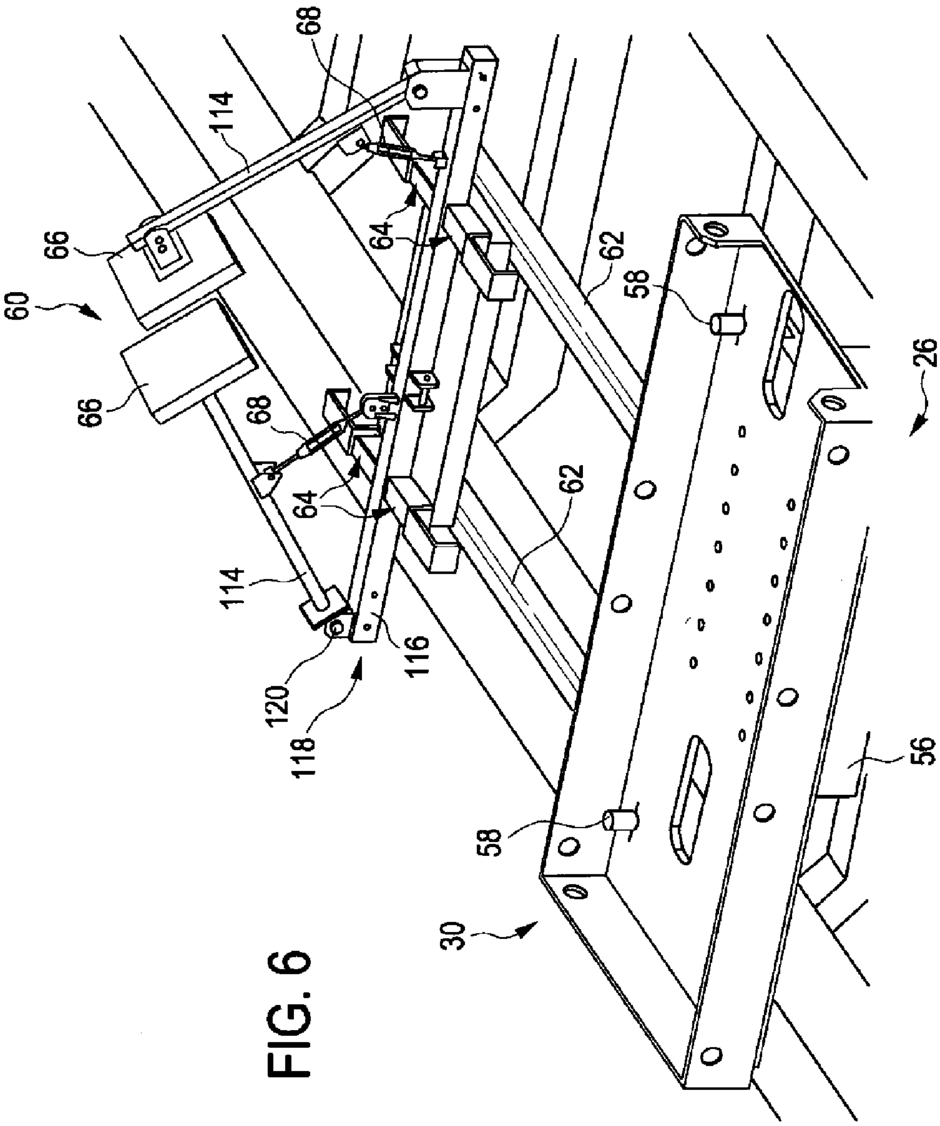


FIG. 6

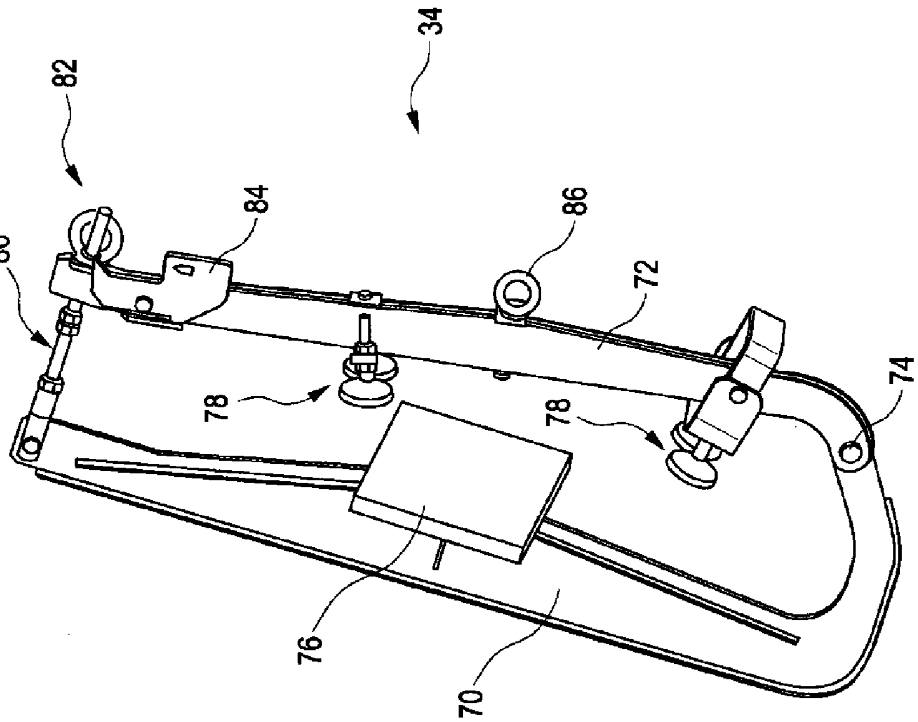
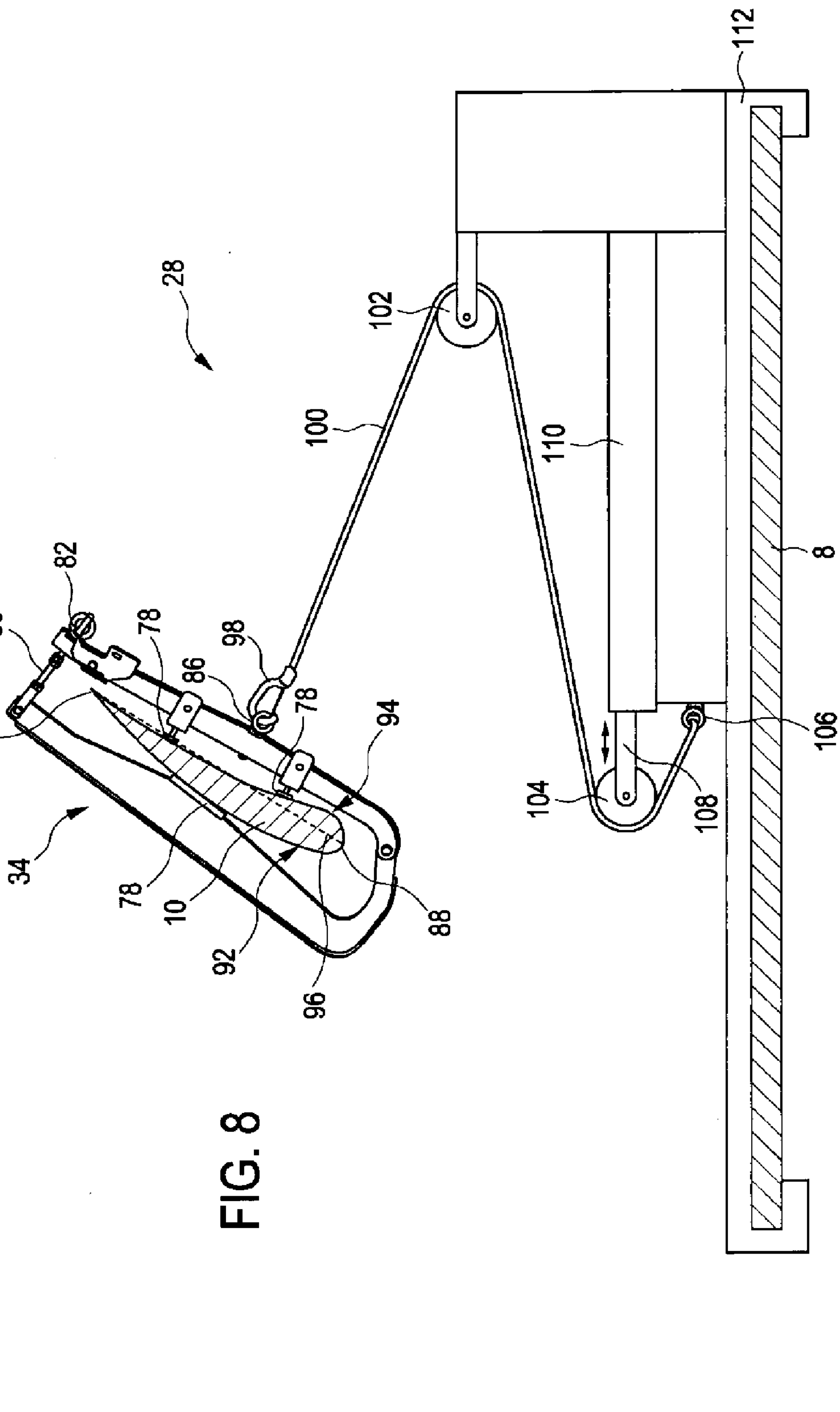


FIG. 7


112
28
102
100
110
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86
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94
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92
96

FIG. 8

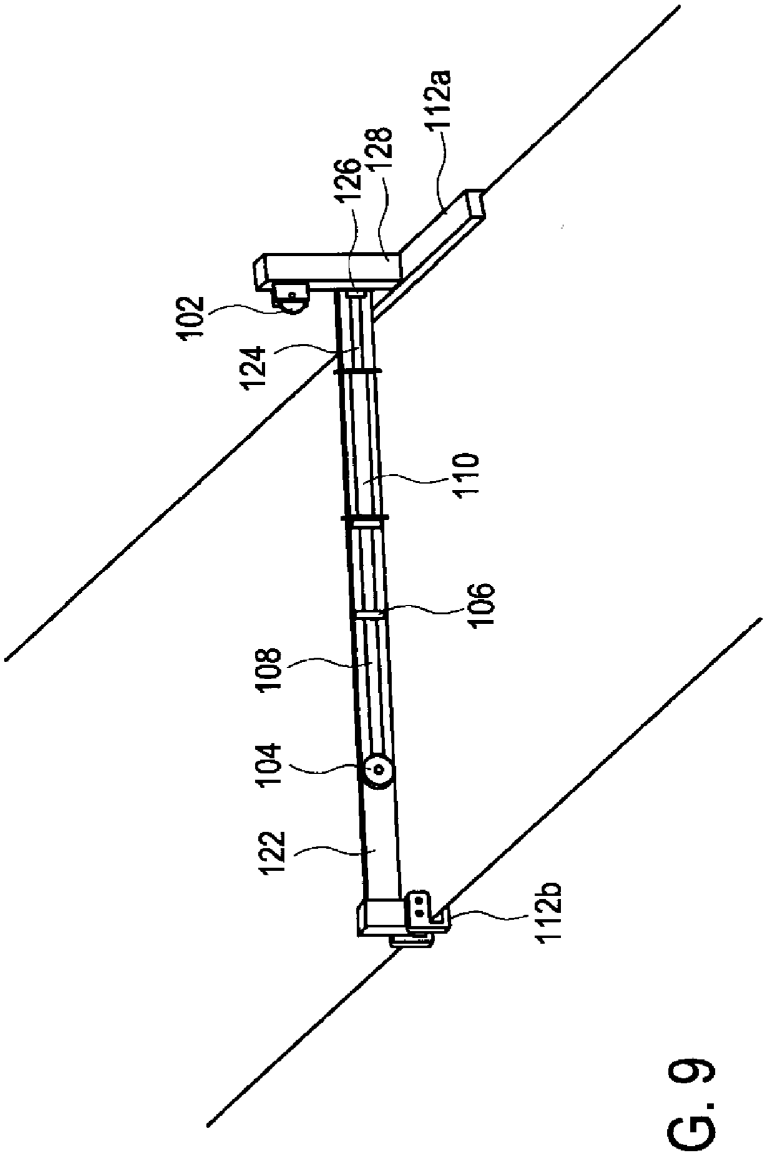

FIG. 9

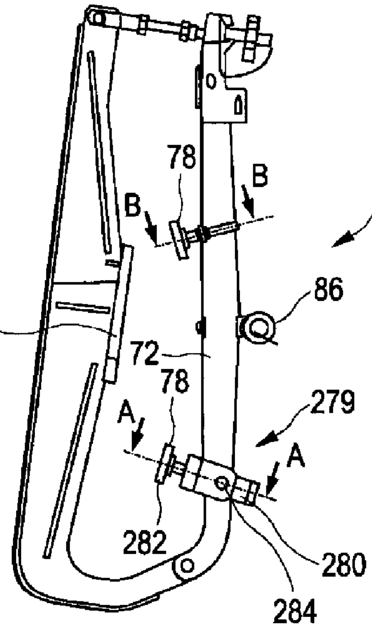

FIG. 10

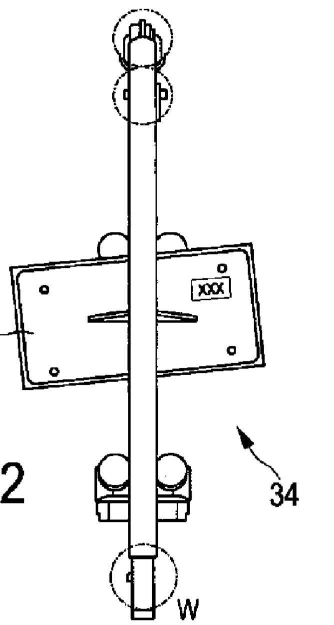

FIG. 12

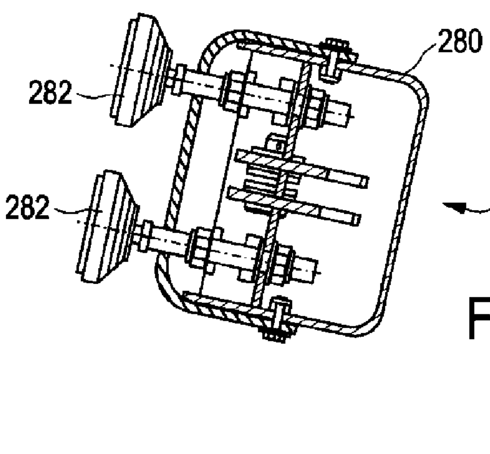

FIG. 11

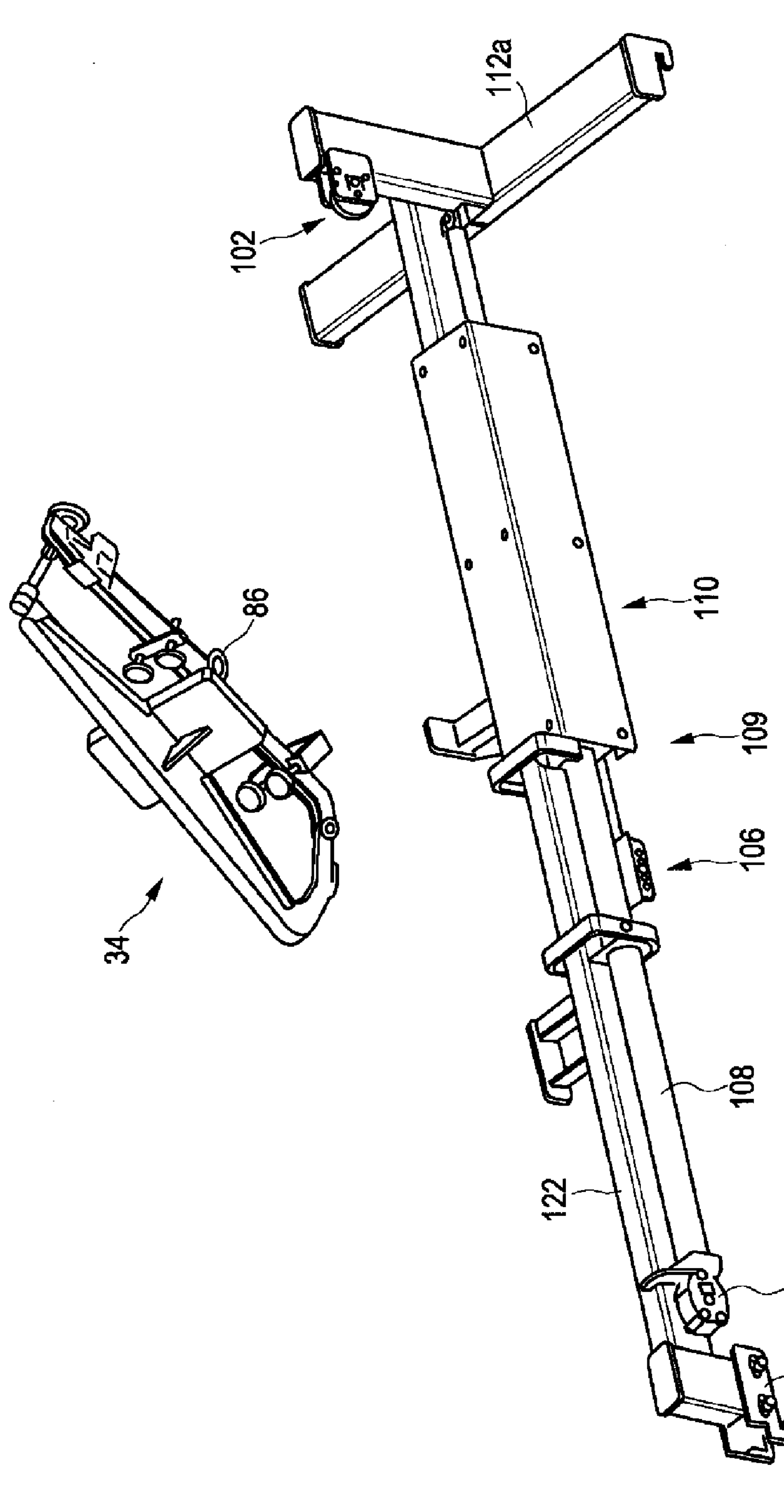

FIG. 13

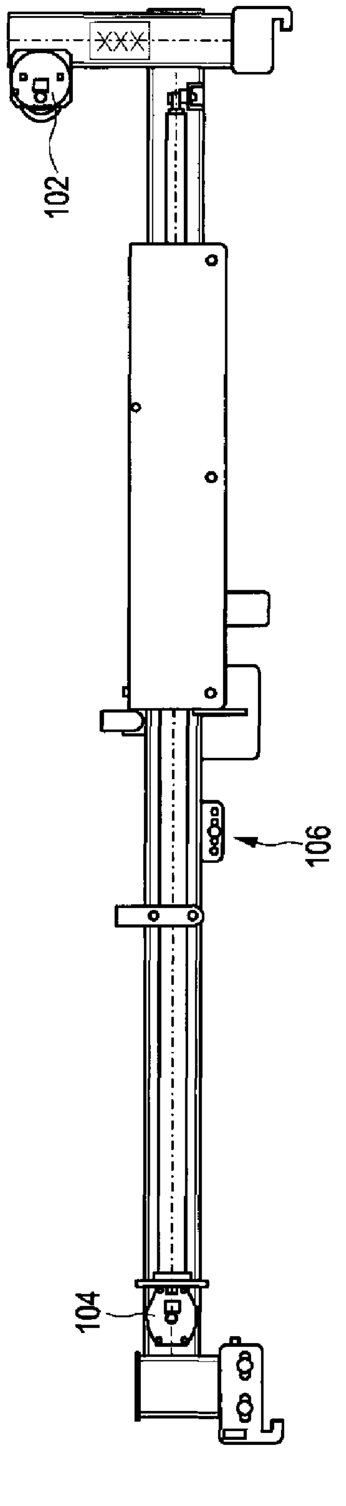

FIG. 14

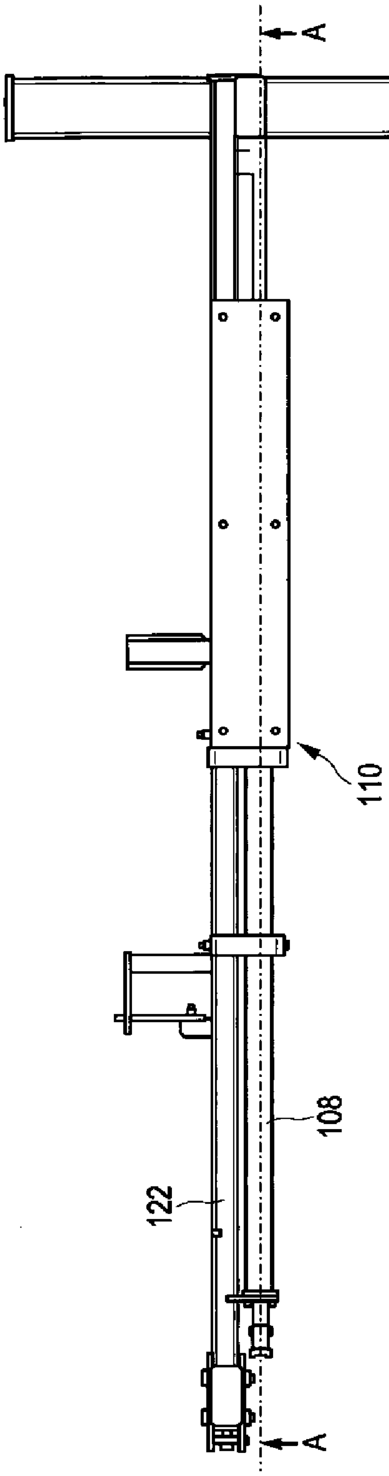

FIG. 15

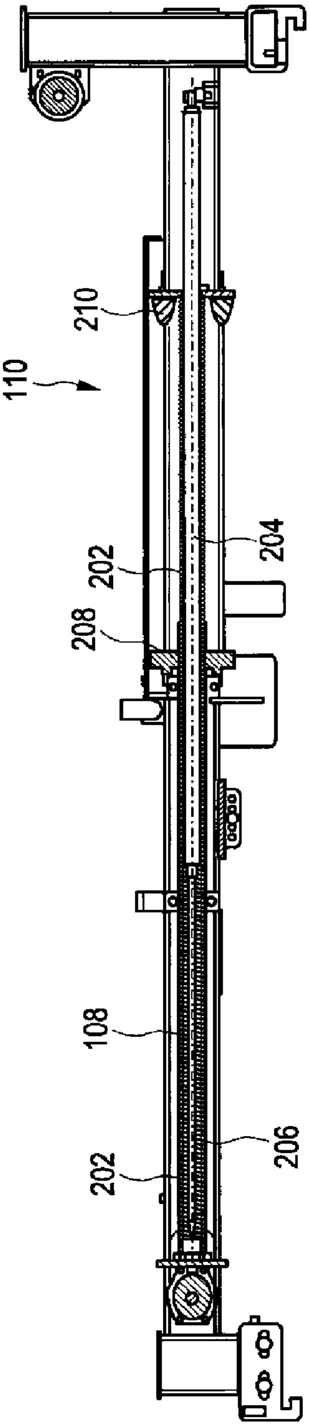

FIG. 16

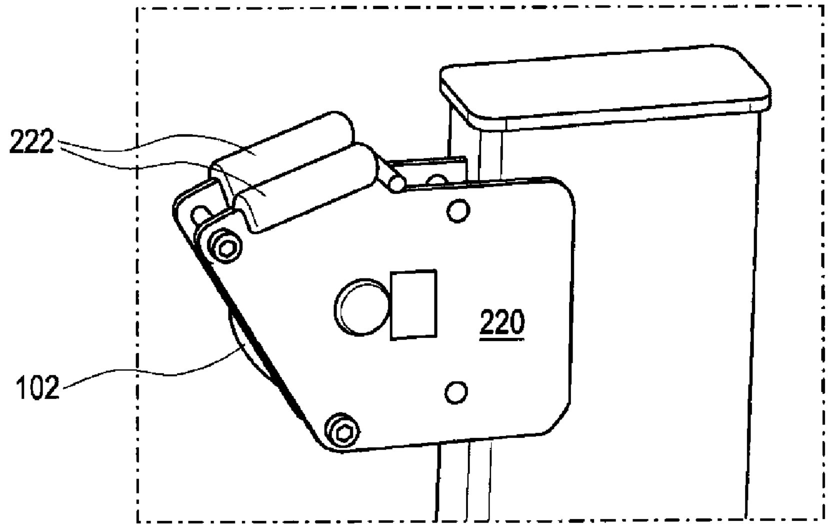

FIG. 17

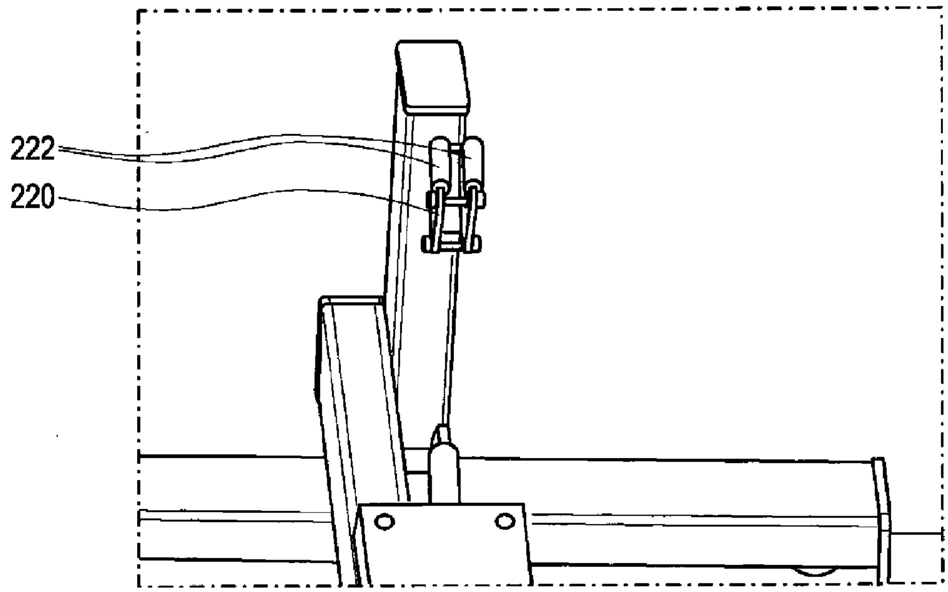

FIG. 18

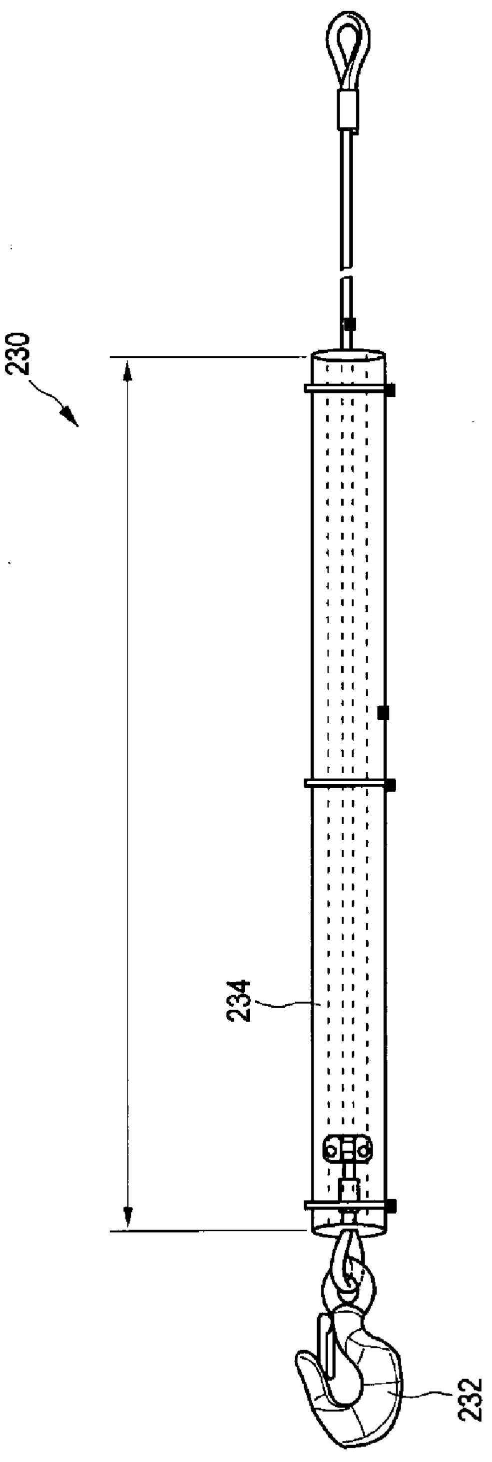

FIG. 19