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(54) Benævnelse: **TESTBÆNK OG FREMGANGSMÅDE TIL TEST AF EN VINDTURBINES TRANSMISSION**

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Description

The invention relates to a test bench for testing a drive train of a wind energy installation, comprising a drive device for introducing a test power into the drive train, which drive device can be releasably connected to a drive train to be tested. The invention further relates to a method for testing a drive train of a wind energy installation using a test bench, and a drive train of a wind energy installation.

In the sector of the construction of wind energy installation, components, specifically mechanical, electrical and/or electronic components, of a wind energy installation are tested in a test bench before the wind energy installation is installed and put into operation. Test benches of this kind, which test individual components of the wind energy installation or a fully assembled nacelle or a fully assembled power house, are also called end-of-line test benches. In addition to control electronics, test benches of this kind comprise one or more motors which transmit a test power or a torque to a drive train, in particular where the rotor is attached to the fully installed wind energy installation. Test benches of this kind are used in a test bench sequence to test whether the mechanical, electrical and/or electronic components correspond to predefined guide values. The test bench sequence can last for a few hours, for example up to 6 hours.

After passing the test, the components or machine houses tested in the test bench are then transported to the installation site, where the wind turbine is installed.

DE 10 2010 017 456 A1 discloses a test bench having a loading apparatus using the example of a test bench for wind energy installations. The loading apparatus comprises a bearing shaft which can be connected to a shaft of the object to be tested and to a drive for transmitting a torque or torsional moment, a load introduction frame which is rotatably mounted on the bearing shaft, and at least one linear drive which is connected to the load introduction frame in order to introduce axial forces and/or radial forces and/or moments.

A test bench for wind turbines is also disclosed in US 2011/0023629 A1. This comprises a main drive and an actuator arrangement, one end of which is designed to

be connected to a shaft of an object to be tested, the actuator arrangement also comprising a shaft.
US 2005/0172729 A1 discloses a test bench for wind energy installations, in which a fixed support structure is anchored on a solid floor, which structure in turn supports a mobile structure which is attached to a rotor shaft of a tower head of a wind energy installation to be tested and acts upon them by means of linear actuators having different loads.

A wind turbine test system is known from WO 2007/140789 A1, in which system a drive train including electronics and generator are built into a test bench, torque is exerted on the slow shaft, and a power grid simulation system is also included such that the test system tests whether the wind energy installation responds to different grid conditions.

The known end-of-line test benches or test benches are anchored to the floor in a stationary manner and have drive devices which are connected to the object to be tested, i.e. to the drive train to be tested, by means of a flexible coupling. A corresponding test bench is known for example from WO 2007/140789 A1. Such end-of-line test benches are very complex and inflexible and are generally only adapted to one type of drive train.

Ideally, a complete machine nacelle is tested. At a weight of more than 320 tons and dimensions of approx. 6 x 19 m, it is not very mobile in the applicant’s wind energy installations marketed under the names 5M and 6M. The preparation and testing in the test bench are correspondingly complex.

The object of the present invention is that of providing a test bench and a method for testing a drive train of a wind energy installation under realistic conditions, by means of which flexible adaptation to different types of wind energy installations is possible, while keeping the design complexity low.

This object is achieved by a test bench for testing a drive train of a wind energy installation, comprising a drive device for introducing a test power into the drive train, which drive device can be releasably connected to a drive train to be tested, which is characterized in that, in order to test a drive train, the drive device is releasably mounted on or to, or attached on or to and supported by, the drive train, wherein, when the drive device is in the mounted or attached condition, a predominant part of the weight force of the drive device bears on the drive train.

Unlike in the prior art, the test bench according to the invention is therefore not anchored to the floor in a stationary manner, but rather has a drive device which is preferably freely movable when it is in the removed condition and, in order to test a drive train, is attached on or to the drive train. In addition, a predominant part of the weight force, in particular more than 50% of the weight force, of the drive device is mounted such that it bears on the drive train.

In comparison with the usual procedure in which the drive device is connected to the object to be tested by means of a flexible coupling, this makes a significantly more realistic testing of the drive train possible.

Within the scope of the invention, a single drive train, i.e. a rotor shaft or a drive train without rotor shaft and optionally having further components, such as a gearbox or a fast shaft, etc., can be tested that is or are alone or is or are built into a machine nacelle or a machine housing.

A drive flange of the drive train, on or to which the drive device is fastened, is preferably used to attach the drive device to or on the drive train. The drive flange can be arranged, for example, on a rotor shaft and can be connected to a rotor hub during operation of the wind energy installation, or can also be used for fastening a rotor hub in the case of a drive without a rotor shaft. The drive flange can alternatively also be part of the rotor hub, which in this case belongs to the drive train to be tested. The drive unit can also engage in a suitable manner on the one or more flanges for the rotor blade or the rotor blades on the rotor hub.

The part of the weight force of the drive device which, in the mounted condition, is borne by the drive train preferably corresponds to a weight force of a rotor of the wind energy installation. This tests the drive train under realistic conditions. The mobile test bench according to the invention or its drive device therefore preferably has a weight which is of the order of magnitude or somewhat above the weight of the rotor of the fully assembled wind energy installation.

In modern wind energy installations, for example the wind energy installations marketed by the applicant under the names 5M or 6M, the machine house has a weight of over 300 tons. The rotor of the 5M has a weight of 130 tons. A compactly built test drive, in particular supported in a cantilever type manner, at a weight of 50 to 150 tons is significantly more mobile than a nacelle at a weight of more than 300 tons. Since the test bench also has a substantially lower number of operating hours than the wind turbines, it can be designed to be significantly lighter and more compact than the wind energy installation nacelle.

The weight or the mass moment of the drive is preferably most effective when it corresponds to the rotor of the smallest system to be tested. Optionally, the mass is advantageously adapted to values of larger rotors by means of trim weights. As a result, more realistic overall masses, nacelle deformations and possibly even drive train inertia can be simulated by the simulated rotor mass.

Alternatively, if the drive weighs more than the rotor of the smallest system to be tested, part of the weight is transferred directly to the ground.

The bearing of the drive device on the drive train is preferably a cantilever type bearing. Thus, the drive train is not unnecessarily or excessively axially loaded. This also helps to protect the drive train.

The particular advantage of flying storage is that there is no need for the time-consuming, precise alignment of the drive unit to the drive train.

Intermediate flanges are advantageously provided for different installations. This makes it possible for the test bench to be used flexibly if the installations have different flanges.

The drive device preferably comprises a large gearwheel which can be mounted on a drive flange, as well as one or more pinions which engage on or in the circumference of the large gearwheel in an external toothing or internal toothing of the large gearwheel. The pinions are preferably evenly distributed around the circumference of the large gearwheel. Due to the plurality or large number of pinions, each pinion is only involved to a small extent in the introduction of the test power or the test torque onto the large gearwheel and thus the drive train. This protects the material of the drive device. A uniform load in the circumferential direction can also be achieved in this way, and therefore unbalances which are harmful to the drive device and the object to be tested are avoided.

Alternatively, an electrical direct drive without teeth is also preferably provided.

The drive device has one or more, in particular hydraulic or electric, drive motors. In the case of hydraulic drive motors, a stationary hydraulic unit for supplying the hydraulic drive motors is preferably provided.

The drive motors preferably each act on a pinion, wherein the drive motors are synchronized, in particular by means of a hydraulic ring means or by an electronic control facility. A hydraulic ring mains which interconnects the hydraulic drive motors ensures that the test power effect is distributed evenly around the circumference. An electronic control facility which synchronizes the electric motors can also be used according to the invention. In particular, it can recognize, reduce and compensate for increased load conditions of individual electric motors by means of the other electric motors, and therefore the effect of the load is evened out.

The drive device advantageously comprises a torque support which in particular comprises two support feet which are supported on the ground. This torque support supports the smaller part of the weight force of the drive device with respect to the ground and absorbs the torque which is exerted by the drive device on the object to be tested.

The torque support preferably comprises a forced load compensation, in particular a cross-feed hydraulic system or piezo elements. The introduction of torques free of constraint means that no transverse forces are introduced into the structure by the required support of the torque on the ground, and therefore the drive train is not deformed or loaded by a radial deviation of the drive device under the influence of the introduced test torque. This is preferably achieved by means of a cross-feed hydraulic system, in which two hydraulic cylinders are cross-connected in the force flow of the torque support such that they can only absorb two opposite forces of the same magnitude, and therefore the total force is always zero. This results in freedom from transverse forces. The freedom from constraint load or freedom from constraint forces serves to protect the object to be tested. This object is therefore not pre-damaged during the test. Instead of a cross-feed hydraulic system, a constraint load compensation can advantageously also be carried out by piezo elements which are highly loadable and can be controlled quickly.

If the machine nacelle is sufficiently heavy, the transport support of the nacelle can be sufficient to support the drive train torque in an advantageous simple embodiment. Otherwise, appropriate design measures, e.g. by widening the contact area ensure a safe introduction of the torque into the ground.

In an advantageous development, the drive device comprises a holding device from which the drive device can be suspended, in particular wherein the holding device comprises a plurality of retaining openings or an elongated hole, in particular with latching positions, for a lifting apparatus or other lifting means, by means of which an axial inclination of the drive device can be adjusted when the drive device is in the suspended condition. Using the holding device, it is possible to move the drive device of the test bench freely, for example in a test hall on a ceiling rail system which has a high load capacity, and to bring it from one drive train to the next drive train without having to move the drive trains or nacelles themselves. The axial inclination can preferably be adjusted between 0° and 10°, in particular between 4° and 7°.

The feature that the holding device has a plurality of retaining openings for a lifting apparatus or another lifting means, or a corresponding elongated hole provided with latching positions means that, depending on which retaining opening is used for the lifting apparatus, the center of gravity of the drive device is located at a different position under the selected retaining opening, and therefore the drive device has a different axial inclination for each retaining opening. The retaining openings or latching positions are in particular arranged in such a way that predetermined axial inclinations of known drive train types and in particular nacelle types of different types of wind energy installations can be adjusted. The drive device of the test bench according to the invention can then be raised in such a way that it already has the correct axial inclination and can therefore be placed in correct alignment on the drive train of the wind energy installation to be tested.

The drive device according to the invention of the test bench according to the invention can be used regardless of the axial inclination of the installation to be tested and no large stationary test bench structures are required. The test bench is flexible in use

and could optionally be pre-installed while the test bench space is still occupied by another object to be tested.
Using the mobile test bench according to the invention, a drive train, optionally in the nacelle, can also be tested on site if the drive unit is attached to the drive train by means of a crane. In this case, an energy supply and torque support must be implemented. For large offshore projects, it is also possible to carry out the desired end-of-line test at the quay edge of a port with the appropriate infrastructure.

With regard to its electric or hydraulic energy supply, the test bench according to the invention requires an existing infrastructure, and optionally also a network connection into which the generator of the object to be tested feeds in the energy. It is also possible to create a circuit in which the majority of the drive energy required is provided by the generator of the tested wind energy installation.

The object on which the invention is based is also achieved by a method for testing a drive train of a wind energy installation using a test bench which is designed in particular according to the invention as described above, which method is characterized in that a drive device of the test bench is mounted on or to, or attached on or to a drive train, wherein, in the mounted condition, a predominant part of the weight force of the drive device bears on the drive train. The drive device is in particular designed to be freely movable. The method has the same advantages, features and properties as the test bench according to the invention.

The part of the weight force of the drive device which bears on the drive train preferably corresponds to a weight force of a rotor of the wind energy installation. This makes a realistic simulation of wind energy installation operation possible.

The method according to the invention also allows the drive device to be advantageously tested on a plurality of drive trains, wherein in each case the drive device is moved from a drive train which has been tested to a drive train to be tested.

Finally, the object on which the invention is based is finally achieved by a drive train of a wind energy installation that is characterized in that it has been tested by means of a previously described method according to the invention and/or by means of a previously described test bench according to the invention. This drive train has thus undergone testing under realistic load conditions and is therefore less likely to fail than drive trains tested in conventional stationary test benches.

A wind energy installation which has a corresponding drive train according to the invention also achieves the object on which the invention is based.

Further features of the invention will become apparent from the description of embodiments according to the invention together with the claims and the accompanying drawings. Embodiments according to the invention can fulfil individual features or a combination of several features.

The invention is described below, without restricting the general inventive concept, on the basis of embodiments with reference to the drawings, reference being expressly made to the drawings with regard to all details according to the invention not explained in more detail in the text, in which:

Fig. 1 shows a schematic cross-sectional view through a nacelle of a wind energy installation with the test bench according to the invention placed thereon, and

Fig. 2 shows a schematic view of a cross- feed hydraulic system.

In the drawings, the same or similar elements and/or parts are provided with the same reference numerals, so that each concept is not repeated.

Fig. 1 shows a cross-sectional view through a nacelle 3 of a known wind energy installation, for example the applicant’s MD70 wind energy installation. The nacelle 3 houses a machine support 12 which is connected to a tower head slewing ring 7. Azimuth adjustment motors 9 of an azimuth adjustment engage on the tower head slewing ring 7, which motors orient the nacelle 3 or the rotor in the direction of the prevailing wind direction after installation and during operation. For this purpose, four azimuth adjustment motors 9 are provided, two of which are arranged on the side shown and two concealed behind it on the other side of the machine support 12. Azimuth brakes 11 also engage on the tower head slewing ring 7, which brakes are used to lock the azimuth setting of the rotor.

The drive train to be tested begins with a rotor shaft 13 which is rotatably mounted in a rotor bearing 14 designed as a roller bearing. In the applicant's MD70 wind energy installation, the rotor bearing 14 is designed as a fixed bearing that allows only a few millimeters of play in the axial direction of the rotor shaft 13. The rotor shaft 13 drives a gearbox 15 which converts the slow rotational movement of the rotor shaft into a fast rotational movement of a generator shaft 19 which is shown having couplings and in turn drives a generator 20 in order to generate power that is equipped with a heat exchanger 21.
The gearbox 15 also has a rotor brake 17 and a slip ring transmission means 18, and two elastic gearbox suspensions or supports 16, one of which is shown in Fig. 1, while the other is located symmetrically on the other side of the gearbox 15 and is therefore concealed by the gearbox 15.

The support or the elastic gearbox suspension 16 is designed conventionally and consists of hollow cylindrical elastomer bodies made of two semi-cylindrical partial bodies which are arranged around a cylindrical bolt. With its cylindrical bearings, the cylinder axis of which is aligned in parallel with the rotor shaft 13, the support 16 is a floating bearing, since, due to its softness in this direction, it absorbs only a small amount of rotor thrust in the direction of the rotor shaft axis.

The nacelle 3 is arranged for testing on a bearing frame 31 and is rigidly supported with respect to the ground by means of feet 32, 32' and bolts 33, 33'.

A drive device 40 according to the invention of a test bench 1 according to the invention rests on a drive flange 5 arranged on the rotor shaft 13. Reference sign 6 denotes a pitch cabinet for the blade adjustment that is fastened to the drive flange 5. In a housing, the drive device has a large gearwheel 41 which rests on the drive flange 5 of the rotor shaft 13. A rotation of the large gearwheel 41 therefore also leads to a rotation of the drive train. Distributed around the circumference of the large gearwheel 41 are a plurality of pinions 42, i.e. small gearwheels, the gearwheels of which act on the gearwheels of the large gearwheel 41. Each pinion is provided with a motor 43 which drives the pinion 42. The motors 43 can be electric or hydraulic. Only two pinions 42 and drive motors 43 are shown in the sectional view in Fig. 1, but it will usually be necessary to use a large number of drive motors 43.

The drive motors require an energy supply, not shown, e.g. by means of electrical cables or hydraulic high-pressure hoses. The claimed feature “freely movable” includes that it can be limited by the energy supply, e.g. due to the cable/hose length. Functionally, however, the drive device 40 can be moved and rotated in all directions with respect to the object to be tested.

The housing or the drive device 40 has a torque support 45 which is seated on the ground 30 by means of a foot 46 or support foot. This torque support 45 ensures that the torque which is transmitted by the large gearwheel 41 to the drive train in the nacelle 3 is conducted away to the ground 30. The torque support also has a cross-feed hydraulic system 60 which prevents radial deviation and causes constraint load compensation.

The drive device 40 also has a holding device 48 at its upper end, in the upper region of which holding device a plurality of retaining openings 49 are arranged adjacently to one another. The retaining openings 49 are used to receive a support hook of a lifting apparatus 52, such that the drive device 40 can be held and moved by a trolley 51 on a support rail 50 via the lifting apparatus 52. The various retaining openings 49 are arranged at different positions in the longitudinal direction, such that a specific axial inclination of the drive device 40 is set by selecting a specific retaining opening 49. This means that the axial inclination can be adapted to the axial inclination of the drive train in the relevant machine house before coupling to a drive train.
Overhead cranes having chains, steel cables or crane slips can be provided as the lifting apparatus. Alternatively, however, rolling carriages having corresponding adjusters for setting the height and angle can also be provided. This is particularly advantageous when no overhead crane with a sufficient load capacity is available.

The principle of a cross-feed hydraulic system 60 is shown schematically in Fig. 2. This system comprises two hydraulic cylinders or hydraulic cylinders 61, 61’, each having a piston 62, 62’ which divides the interior of the hydraulic cylinders 61, 61’ into an upper partial volume 63, 63’ and a lower partial volume 64, 64’. The pistons are each acted upon by the force from above, which, for example, applies the weight force or the relevant force which results from a torque from the drive device 40. As a result, the two pistons 62, 62’ are pressed downward and the lower partial space 64, 64’ is reduced in size in each case.

Hydraulic lines 65, 66 are provided between the upper partial volume 63 of the hydraulic cylinder 61 and the lower partial volume 64’ of the hydraulic cylinder 61’ and the lower partial volume 64 of the hydraulic cylinder 61 and the upper partial volume 63’ of the hydraulic cylinder 61’, through which lines the hydraulic fluid in the interconnected partial volumes communicates. This results in an increased pressure on the piston 62 of the hydraulic cylinder 61 leading to a further reduction in the lower partial volume 64, for example. Via the connecting line 66, this pressure is passed on to the piston 62’ in the hydraulic cylinder 61’ which is also further loaded. This can be used, for example, to compensate for a torque which acts in such a way that the torque may actually move the piston 62’ upward. This cross-feed hydraulic system thus causes radial deviation which is generated by the torque of the drive device 40 to be prevented and the drive device 40 to not be moved with respect to the drive train. The crossover also causes the absorbed total force to be zero.

All of the features mentioned, including those which can be seen in the drawings alone and also individual features which are disclosed in combination with other features, are considered to be essential to the invention, alone and in combination. Embodiments according to the invention can be fulfilled by individual features or a combination of several features.

List of reference signs

1	Test bench
3	Nacelle
5	Drive flange
6	Pitch cabinet
7	Tower head slewing ring
9	Azimuth adjustment motors
11	Azimuth brakes
12	Machine support
13	Rotor shaft
14	Rotor bearing
15	Gearbox
16	Elastic gearbox suspension
17	Rotor brake
18	Slip ring transmission means
19	Generator shaft having couplings
20	Generator
21	Heat exchanger
30	Ground

31 Bearing frame

32, 32’ Foot

33, 33’ Bolt

40 Drive device

41 Large gear wheel

42 Pinion

43 Drive motor

45 Torque support

46 Foot

48 Holding device

49 Retaining opening

50 Support rail

51 Trolley

52 Lifting apparatus

60 Cross-feed hydraulic system

61, 61’ Hydraulic cylinder

62, 62’ Piston

63, 63’ Upper partial volume

64, 64’ Lower partial volume

65, 66 Hydraulic line

Patentkrav

1. En testbænk (1) til test af en transmission i en vindenergiinstallation, der omfatter en drivanordning (40) til overførsel af testeffekt ind i en transmission, hvilken drivanordning (40) kan forbindes genudløseligt med en transmission, der skal testes, hvori, for at teste en transmission, drivanordningen (40) er monteret genudløseligt på eller til, eller fastgjort på eller til og understøttet af, transmissionen, **kendetegnet ved, at**, når drivanordningen (40) er i den monterede eller fastgjorte tilstand, en overvejende del af vægtkraften af drivanordningen (40) tynger transmissionen, og drivanordningen (40) omfatter én eller flere drivmotorer (43), specielt én eller flere hydrauliske eller elektriske drivmotorer (43).

2. Testbænken (1) i henhold til krav 1, **kendetegnet ved, at** drivanordningen (40) kan bevæges frit, når den er i den aftaget tilstand.

3. Testbænken (1) i henhold til krav 1 eller 2, **kendetegnet ved, at** den del af vægtkraften af drivanordningen (40), som i den monterede tilstand bæres af transmissionen, svarer til en vægtkraft af en rotor i vindenergiinstallationen.

4. Testbænken (1) i henhold til ethvert af kravene 1 til 3, **kendetegnet ved, at** lejet i drivanordningen (40) på transmissionen er et leje af udliggertype.

5. Testbænken (1) i henhold til ethvert af kravene 1 til 4, **kendetegnet ved, at** drivanordningen (40) omfatter et stort gearhjul (41), der kan monteres på en drivflange (5), samt ét eller flere drevhjul (42), der går i indgreb med eller i omkredsen af det store gearhjul (41) i en ekstern fortanding eller en intern fortanding på det store gearhjul (41).

6. Testbænken (1) i henhold til ethvert af kravene 1 til 5, **kendetegnet ved, at** drivmotorerne (43) hver fungerer på et respektivt drevhjul (42), hvori drivmotorerne (43) er synkroniseret og specifikt ved hjælp af en hydraulisk ringformet ledning eller en elektronisk styring.

7. Testbænken (1) i henhold til ethvert af kravene 1 til 6, **kendetegnet ved, at** drivanordningen (40) omfatter en momentstøtte (45), der specielt omfatter to støttefødder (46), der er placeret som støtte på underlaget.

8. Testbænken (1) i henhold til krav 7, **kendetegnet ved, at** momentstøtten (45) omfatter en tvangsbelastningskompensation, specielt et hydraulisk system med tværgående forsyning (60) eller piezoelementer.

9. Testbænken (1) i henhold til ethvert af kravene 1 til 8, **kendetegnet ved, at** drivanordningen (40) omfatter en holdeanordning (48), hvorfra drivanordningen (40) kan ophænges, specielt hvori holdeanordningen (48) omfatter en pluralitet af holdeåbninger (49) eller et aflangt hul, specielt med låsepositioner, til en løfteanordning (52), hvormed en aksial hældning af drivanordningen (40) kan justeres, når drivanordningen er ophængt.

10. En fremgangsmåde til test af en transmission i en vindenergiinstallation ved hjælp af en testbænk (1), specielt i henhold til ethvert af kravene 1 til 9, hvori en drivanordning (40) på testbænken (1) er monteret på eller til, eller fastgjort på eller til en transmission, **kendetegnet ved, at** i den monterede tilstand bæres en hoveddel af drivanordningens (40) vægtkraft af transmissionen, og drivanordningen (40) omfatter én eller flere drivmotorer (43), specielt én eller flere hydrauliske eller elektriske drivmotorer (43).

11. Fremgangsmåden i henhold til krav 10, **kendetegnet ved, at** den del af vægtkraften af drivanordningen (40), som bæres af transmissionen, svarer til en vægtkraft af en rotor i vindenergiinstallationen.

12. Fremgangsmåden i henhold til krav 10 eller 11, **kendetegnet ved, at** testen, der anvender drivanordningen (40), udføres på en pluralitet af transmissioner, hvori drivanordningen (40) i alle tilfælde flyttes fra en transmission, der er blevet testet, til en transmission, der skal testes.

13. En transmission i en vindenergiinstallation, **kendetegnet ved, at** den er blevet testet ved hjælp af en metode i henhold til ethvert af kravene 10 til 12 og / eller ved hjælp af en testbænk (1) i henhold til ethvert af kravene 1 til 9.

Fig. 1

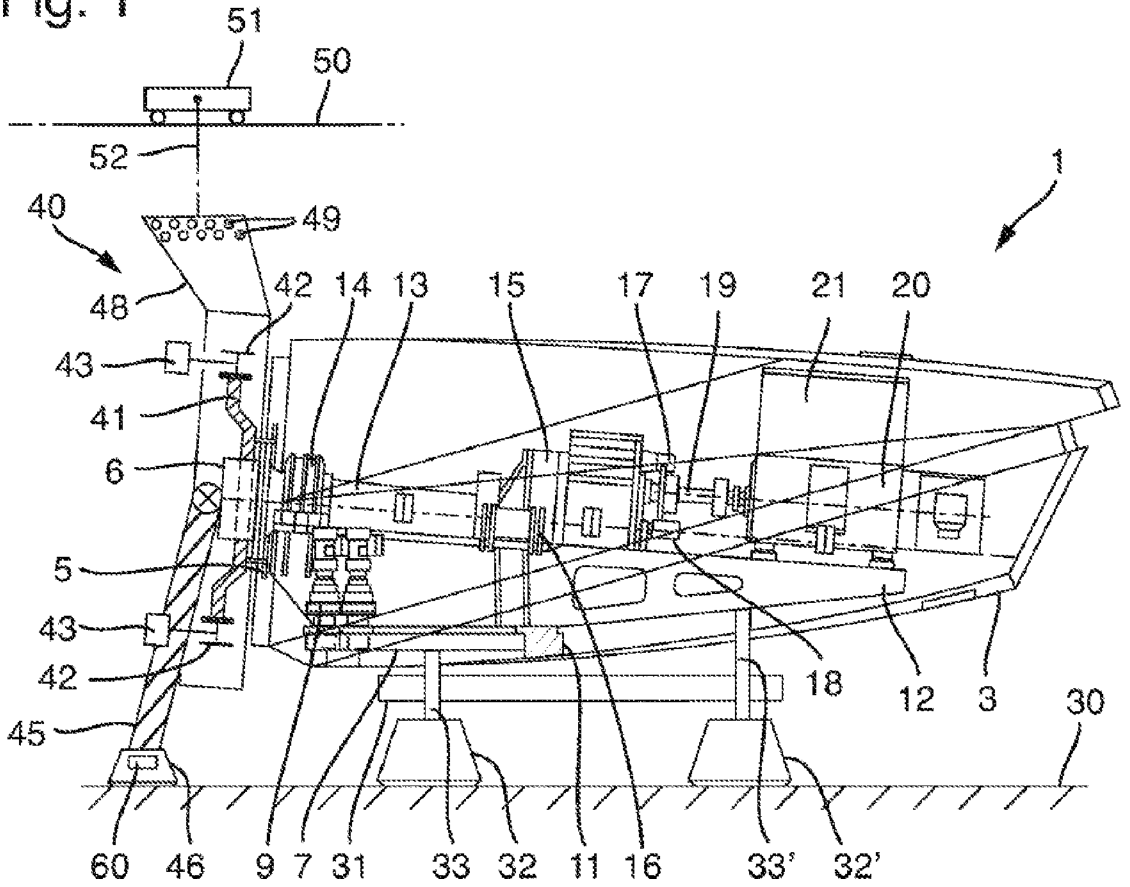

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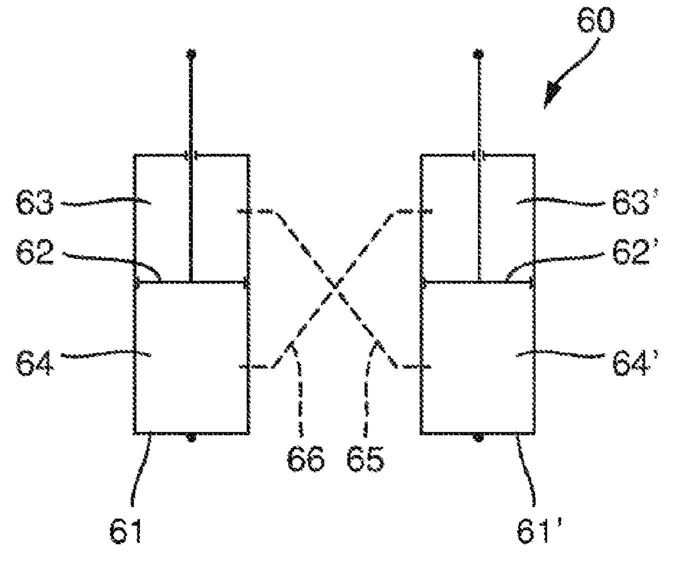
Fig. 2



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