

(19)



(11)

EP 4 556 359 A1

(12)

EUROPEAN PATENT APPLICATION

(43) Date of publication:
21.05.2025 Bulletin 2025/21

(51) International Patent Classification (IPC):
B63B 21/02 (2006.01)

(21) Application number: **23000164.6**

(52) Cooperative Patent Classification (CPC):
B63B 21/02

(22) Date of filing: **17.11.2023**

(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 ME MK MT NL
NO PL PT RO RS SE SI SK SM TR**
Designated Extension States:
BA
Designated Validation States:
KH MA MD TN

(72) Inventors:
• **Kolakowski, Pawel**
81-472 Gdynia (PL)
• **Koznowski, Wojciech**
84-217 Szemud (PL)
• **Lebkowski, Andrzej**
81-256 Gdynia (PL)
• **Rutkowski, Grzegorz**
81-575 Gdynia (PL)

(71) Applicant: **Uniwersytet Morski w Gdyni**
81-225 Gdynia (PL)

(54) SHIP DOCKING GRIPPER AND DOCKING METHOD FOR SMALL FLOATING UNITS

(57) The subject of the invention is a ship gripper designed for docking small floating units in hard-to-reach areas and a method for docking small floating units using the ship gripper. The invention is dedicated to floating

service units and is applicable in maritime mooring systems or ship docking systems for offshore installations such as offshore wind power plants, power stations, ship loading facilities, or floating fuel depots.

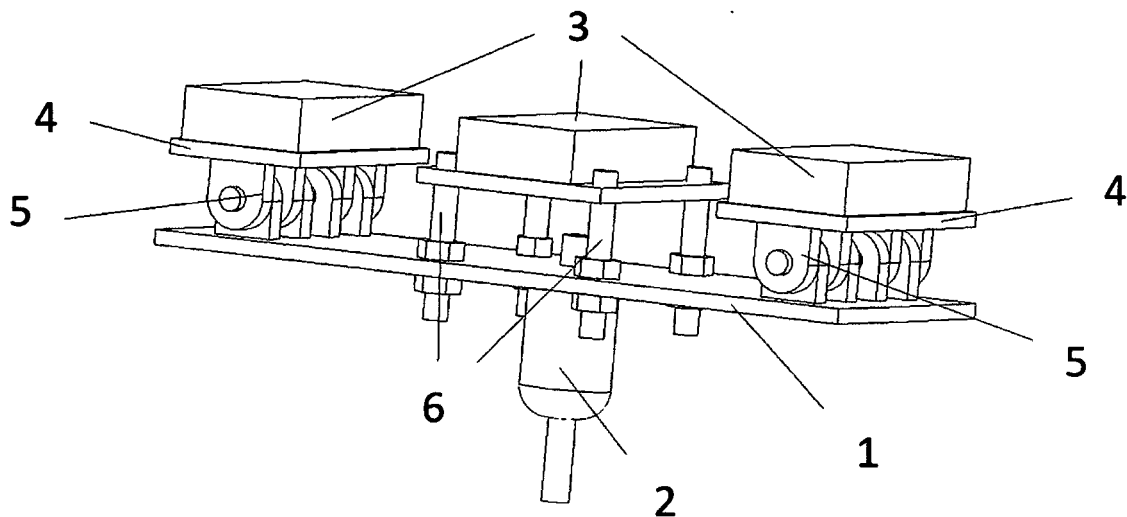


Fig. 6

Description

[0001] The invention relates to a ship gripper designed for docking small floating units in hard-to-reach areas and a method for docking small floating units using the ship gripper. The invention is dedicated to floating service units and is applicable in maritime mooring systems or ship docking systems for offshore installations such as offshore wind power plants, power stations, ship loading facilities, or floating fuel depots.

[0002] Devices enabling ship mooring using impact energy damping forces and electromagnetic forces are known from the prior state of the art. Patent application P.400289 discloses solutions related to port fenders, where the protective system for the port wall includes fenders distributed along the quay wall to absorb the impact energy from a ship approaching the wall. In this solution, at least one fender contains a movable mechanical buffer with a part for receiving collision energy, designed to come into contact with the approaching ship, and a coupling part coupled to a rotating energy accumulator containing a rotor for absorbing, in rotational motion, at least a portion of the kinetic energy of the movable buffer.

[0003] Patent application P.401694, on the other hand, discloses a fender containing a system for absorbing impact energy, which is mounted between the impact-receiving element and the mounting plate for attaching the fender to the port quay wall. Polish patent document PL232697 describes a ship mooring device consisting of a fender with a front panel containing at least one electromagnetic module connected to the power supply system of this module. The front panel is equipped with fastening elements for attaching the panel to the quay. The fastening elements include damping means.

[0004] Russian utility model RU.059099 describes a device for mooring a floating object using an arm consisting of a hook and a cooperating mooring actuator, to which the piston of this hook is attached.

[0005] International patent literature points to solutions for mooring a ship to the quay using devices with permanently installed electromagnetic bumpers, not suitable for ship-to-ship mooring or docking to offshore installations.

[0006] Patent application CN107972814 discloses equipment for the mooring device of a ship, including a driving winding, a first pallet disk for lifting, a rope drum, a second pallet disk for lifting, a supporting block, a drive for the rope to the pulley, and windings on both sides suitably equipped with a side shaft. The winding drive is equipped with a first pallet pulley, a rope drum, and a spool. This design is easy to use, stable, and characterized by extended durability.

[0007] Patent application CN104260830 discloses an automatic mooring device consisting of a base, a control box, a main gearbox mechanism, and durable magnetic grips usually located in the dock. Electric, durable magnetic grips ensure a high attraction force to the ship's hull, and the base is connected to a movable frame through a

hydraulic drive arm and crankshafts equipped with sliding guides. Hydraulic rods are placed on the sliding guides and are extended and retracted to drive sliding blocks connected to hydraulic rods. This design allows for vertical movement of the arm on vertical sliding guides parallel to hydraulic rods, achieving the appropriate height of the magnetically attracted hull surface in the selected area of the ship's hull. Controlled multi-directional movement of durable magnetic grips improves the efficiency and safety of the traditional mooring method.

[0008] Another solution is the AutoMoor mooring system, produced by Trelleborg Marine & Infrastructure, based on a stationary land system of actuators and vacuum mooring cushions. Its task is to moor large ships to the quay during unloading or loading. Despite ensuring a short mooring time and increasing the safety of port personnel due to the automation of mooring operations, it is necessary to keep the hull of the moored vessel clean. This is associated with the need for continuous removal of fouling and algae from the hull surface, which reduces the effectiveness of the suction cups used in this solution. Another inconvenience of this type of system is the need for an extensive quay apparatus structure and the high costs associated with its installation.

[0009] All these inventions are large-scale port devices that cannot be used on small watercraft in ship-to-ship or ship-to-shore infrastructure or offshore installation mooring systems. Additionally, they are complete mooring systems requiring an external power supply.

[0010] Solutions based on electromagnetic mooring arms are described in the mentioned patents EP2844542, CN108674582, and WO2012060511. However, these solutions are also of large dimensions, making them unsuitable for use on smaller service boats not exceeding 30 meters in length. Special electromagnetic grippers allowing horizontal movement of the moored unit along the mooring system have been applied in a mobile electromagnetic mooring system for small surface units revealed in patent applications P.437572 and EP 4 082 888, in this solution, however, there is no possibility of adapting magnets to the curved shapes of wind turbine towers on offshore wind farms or quay infrastructure. Although a device for docking a small floating unit to a maritime wind turbine called the Tube Docking Device has been disclosed in patent application EP2661392, this invention does not use electromagnets but rather hydraulic actuators permanently built into the hull of the floating unit.

[0011] However, there is still a lack of comprehensive, easy-to-use solutions of small dimensions, allowing for smooth and fast mooring system operation regardless of the mooring location, such as offshore wind farms, quays, or floating fuel tanks, and weather conditions, including strong waves, precipitation, and low air and water temperatures.

[0012] The aim of this invention was to develop a simple, small-sized construction enabling stable docking of a service unit to a larger ship, quay, floating fuel tank, or

offshore wind turbine. Unexpectedly, the simple design of the ship gripper for docking, in addition to the small dimensions of the device and relatively low mass, has been equipped with a damping, compensation, and distance assessment system, gaining mobility and reliability as a result.

The essence of the invention is a ship docking gripper for small floating units for use in challenging locations at sea. It comprises a body equipped with electromagnets, arms, securing handles, and an electrical power and control system. The body features a ball joint on the ship side in the central part and is equipped with an electromagnet assembly on the outer side, secured to the body by a connecting hinge or fixed element.

[0013] Advantageously, the body is made of a rectangular aluminum alloy plate, taking the shape of either the letter 'I' or 'T'. The body is equipped with three arms situated on the outer surface - 'T'-shaped at each of the three ends and 'I'-shaped at the two opposing ends and in the middle. The arm positioning adapts to the shape of the docking object's contact plane.

[0014] Advantageously the connecting hinge linking the arms to the body is preferably a stainless-steel hinge, at least 6 mm thick, serving as a damping twisted (butt) hinge. Alternatively, the fixed element connecting the arms to the body is a rectangular section, at least 6 mm thick, either welded or attached to the ship side with at least four adjustable steel pins and nuts.

[0015] Advantageously, the electromagnet assembly consists of at least three individual electromagnets permanently mounted or articulated with eye joints. The arms are equipped with rectangular or circular electromagnets, each with magnetic force adjusted for the specific size of the docking unit and the weather conditions.

[0016] Advantageously, the ball joint on the 'I'-shaped body can be connected to a dynamic compensating column consisting of a crane on a hydraulic actuator, or a mooring winch ensuring proper winding and unwinding of the cable, and a control system.

[0017] Advantageously, the power supply unit for an individual electromagnet is located above the electromagnet from the ship's side, equipped with energy storage, or powered directly from the floating unit. The electrical power control system for the electromagnets is based on controllers, inductive distance sensors, and radio links, comprising a cascading connection of two PI controllers responsible for cable tension regulation and current regulation, along with an emergency system.

[0018] The invention also encompasses a docking method for small floating units using the ship docking gripper. It involves applying a voltage from the power supply unit to the electrical connectors leading to the electromagnets, resulting in a minimum 12V voltage across the coils in the internal windings of the gripper body. This creates a magnetic force on the round or rectangular feet of the electromagnets, attracting the small intervention unit between the magnetic frontside of the gripper and the surface points of another ship, pier

column, or offshore installation. Adjustment is achieved through the connecting hinge, creating a rigid connection in a horizontal position to the waterline. Undocking occurs by disconnecting the voltage to the electromagnets, loosening the connection between the objects, and undocking the floating unit from the surface points of another ship, pier column, or offshore installation. Docking and undocking are remotely controlled through the power-controlled system equipped with inductive distance sensors, remotely monitoring the electromagnetic field force.

[0019] The main advantages of this solution include facilitating the servicing of offshore wind farms by enabling docking in challenging locations or maritime infrastructure with ship docking grippers. The invention reduces the time required for docking and undocking operations, enhancing the safety of mooring, docking, and personnel and cargo transfer at sea. The electromagnet grippers demonstrate mobility and the ability for repeated attachment and detachment. The invention allows for remote device control and a self-powering system through built-in energy storage in the gripper body. The solution is tailored for small floating units - service watercraft, reducing environmental impact by eliminating continuous engine operation and reducing emissions, toxic substances, noise, and vibrations.

The power supply and control system selection for the ship docking gripper allows for versatile applications, suitable for docking systems to offshore installations relying on a dynamically compensating docking column, where power is directly supplied from the service unit or for mooring systems while using mooring winches, the gripper is equipped with a built-in, self-powering source relying on an energy store. Moreover, the ship docking gripper's electromagnetic system can adjust to the curved shapes of wind turbine towers in offshore wind farms or coastal infrastructure. The improvement in efficiency, effectiveness, and safety is evident. The invention enables rapid, automated docking or mooring of small floating units in open seas, ports, or maritime wind farms. The invention is presented in an exemplary embodiment in the drawings, where:

Fig. 1 illustrates a ship docking gripper for docking a small floating unit with an I-shaped hull, shown in a side perspective view.

Fig. 2 illustrates a ship docking gripper for docking a small floating unit with an I-shaped hull, shown in a rear perspective view.

Fig. 3 illustrates a ship docking gripper for docking a small floating unit with an I-shaped hull, shown in a side view.

Fig. 4 illustrates a ship docking gripper for docking a small floating unit with an I-shaped hull, shown in a top view.

Fig. 5 illustrates a ship docking gripper for docking a small floating unit with an I-shaped hull, shown in a front view.

Fig. 6 illustrates a ship docking gripper for docking a small floating unit with an I-shaped hull, shown in a perspective view from the opposite side.

Fig. 7 illustrates a ship docking gripper for docking a small floating unit with a T-shaped hull, shown in a bottom perspective view.

Fig. 8 illustrates a ship docking gripper for docking a small floating unit with a T-shaped hull, shown in a rear perspective view.

Fig. 9 illustrates a ship docking gripper for docking a small floating unit with a T-shaped hull, shown in a side view.

Fig. 10 illustrates a ship docking gripper for docking a small floating unit with a T-shaped hull, shown in a top view.

Fig. 11 illustrates a ship docking gripper for docking a small floating unit with a T-shaped hull, shown in a perspective view from the opposite side.

[0020] The ship docking gripper for docking small floating units in hard-to-reach areas, as shown in Figs. 1 to 11, has been designed using the 3D Fusion 360 program. The design process considered all key elements necessary for developing a reliable docking system for small floating units. The design work used a model of a Merlin 6.15 type boat. The program took into account all material coefficients, the strength of aluminum, steel screws, and the welding of parts. The solution has a high safety factor.

[0021] In the exemplary embodiment shown in Figs. 1 to 6, the ship docking gripper is made of a rectangular aluminum alloy plate and has an I-shaped design. The hull (1) is equipped with three arms (4) located on the outer surface of the hull (1), positioned on two opposite ends of the I-shaped hull, and in the middle. The position of the arms (4) is selected according to the shape of the contact plane with the docking object. The hull (1) is connected to the arms (4), which are connected by a hinge element made of stainless steel, welded with a 6 to 8 mm thick weld, forming a damping articulated butt hinge (5). This solution is stable, simple, and lightweight. The pivoting motion is achieved through hinges made by hand cutting, with an H7/f7 tolerance. TIG welding is used for connection. A solid element connecting the arms (4) to the hull (1) is a rectangular section beam, mounted on the ship's side with four adjustable steel pins with nuts (6). The electromagnet assembly (3) in the invention consists of three electromagnets mounted using eye joints. A single magnetic coil generates a force of 15,500 N. In the execution variant for approaching a service unit to a wind farm infrastructure, a ball joint (2) on the hull (1) is connected to a dynamic compensating column consisting of a crane on a hydraulic actuator, or in other options a mooring winch providing winding and unwinding of the rope, and a control system. The power for a single electromagnet (3) is supplied directly from the floating unit through electric wires, and an electrical power control system for the electromagnets is based on controllers, inductive distance sensors, and radio

links. The control system structure consists of a cascade connection of two PI controllers responsible for rope tension regulation and current regulation, as well as an emergency system. The docking column allows compensation for the unit's movement at sea within a range of up to 0.5m waves.

[0022] In another embodiment shown in Figs. 7 to 11, the ship docking gripper for docking a small floating unit in hard-to-reach areas is constructed with a hull (1) containing a ball joint (2) on the ship's side in the central part and an electromagnet assembly (3) attached to the hull (1) on arms (4) through a fixed connecting element. In this variant, the solution enables stable docking of a small floating unit to a larger ship or offshore construction through a ship docking gripper where the hull (1) is made of a rectangular aluminum alloy plate and has a T-shaped design. The hull (1) is equipped with three arms (4) located on the outer surface of the hull (1), one at each of the three ends of the T-shaped hull, with the position of the arms (4) selected according to the shape of the contact plane with the docking object. The arms (4) with the hull (1) form a rectangular cross-section beam welded with a 6 mm thick weld. The electromagnet assembly (3) in the invention, as shown in Fig. 7, consists of three round, individual electromagnets, each with a magnetic force of 5000N, mounted using eye joints. The power supply for a single electromagnet is located above the electromagnet on the hull (1) on the ship's side and is equipped with energy storage and an electrical power control system for the electromagnets. The control system is based on controllers, inductive distance sensors, and radio links. The control system structure involves a cascaded connection of two PI controllers responsible for rope tension regulation and current regulation, as well as an emergency system enhancing the safety of the solution.

[0023] In another embodiment of the invention, docking a small floating unit using the ship gripper is accomplished by applying voltage from the power supply unit to the electrical connectors leading to the electromagnets (3), providing a minimum voltage of 12V through coils in the internal windings located in the gripper hull (1). The magnetic force generated on the round or rectangular frontside of the electromagnet attracts the small intervention unit to the contact points on the hull of another ship or the column of the quay or offshore installation. The adjustment is achieved through a hinge connecting the arms (4) to the hull (1), which dampens the connecting force. This leads to a rigid connection in a horizontal position to the waterline. This connection allows the safe transfer of people in offshore environments, supplying ships, marine rescue operations, understood as interventions in the repair of maritime units, as well as marine services, hull inspections, or hull cleaning.

Undocking after the transfer of people or cargo is initiated by disconnecting the voltage supplied to the electromagnets from the electrical connectors. This loosens the connection between objects and allows the floating unit

to undock from the points on the hull of another ship or quay column or offshore installation. This process is controlled using a powered control system equipped with inductive distance sensors that remotely control the strength of the electromagnetic field.

For docking systems for offshore installations based on the use of a dynamically compensating docking column shown in Figs. 1 to 6, power is supplied directly from the service unit. In the variant for mooring systems using mooring winches, the ship's electromagnetic gripper shown in Figs. 7 to 11 is equipped with its own energy source, namely energy storage (7). Additionally, in the gripper's hull, there is an entire control system allowing for remote control of the gripper's operation, including automatic or remote engagement, release, and emergency disconnection.

List of designations in the drawings:

[0024]

1. Gripper construction hull
2. Ball joint
3. Electromagnet assembly
4. Electromagnet mounting arms
5. Damping articulated (butt) hinge
6. Adjustable pins countered with nuts
7. Power and control system.

Claims

1. A ship docking gripper for docking a small floating unit in hard-to-reach places, constructed with a body equipped with electromagnets, arms, securing handles, and an electrical power and control system, **characterized in that** the body (1) on the ship's side in the central part contains a ball joint (2), and on the outer side, it is equipped with a set of electromagnets (3) attached to the body (1) on arms (4) through a connecting pivotal or fixed element.
2. The ship docking gripper according to Claim 1, is **characterized in that** the body (1) is made of a flat bar aluminum alloy plate and has the shape of the letter I or T.
3. The ship docking gripper according to Claim 1, is **characterized in that** the body (1) is equipped with three arms (4) located accordingly on the outer side of the body (1) in the shape of the letter T at each of its three ends and in the shape of the letter I at two opposite ends, with the position of the arms (4) being selected according to the shape of the contact plane with the docking object.
4. The ship docking gripper according to Claim 1, is **characterized in that** the pivotal connecting element between the arms (4) and the body (1) is a

stainless steel welded joint with a thickness of at least 6 mm, damping a butt hinge (5).

5. The ship docking gripper according to Claim 1, is **characterized in that** the fixed connecting element between the arms (4) and the body (1) is a rectangular section welded with a thickness of at least 6 mm or attached to the ship's side by at least four adjustable steel pins with nuts (6).
6. The ship docking gripper according to Claim 1, is **characterized in that** the set of electromagnets (3) consists of at least three individual electromagnets, being permanently attached or connected through articulated eye joints.
7. The ship docking gripper according to Claims 1 and 6, is **characterized in that** the arms (4) are equipped with rectangular or circular electromagnets, with a single electromagnet having a magnetic force selected for the desired position depending on the size of the docking unit and the weather conditions.
8. The ship docking gripper according to Claim 1, is **characterized in that** the ball joint (2) on the body (1) can be connected to a dynamic compensating column consisting of a crane on an actuator, or to the mooring winch providing proper winding and unwinding of the rope, and a control system.
9. The ship docking gripper according to Claim 1, is **characterized in that** the power unit for a single electromagnet is located above the electromagnet on the body (1) on the watercraft's side and is equipped with an energy storage, or powered directly by cables from the floating unit, includes an electric power control system based on controllers, inductive distance sensors, and radio links, with the control system structure consisting of a cascading connection of two PI controllers responsible for regulating the rope tension and current regulation, as well as an emergency system.
10. A method for docking a small floating unit with a ship docking gripper, involving the docking and undocking of a small floating unit used in maritime mooring systems based on mooring winches or ship docking systems to another object in a hard-to-reach place, **characterized in that** by applying a voltage from the power unit to the electrical connectors leading to the electromagnets (3) of at least 12V through coils in the internal windings located in the body of the gripper (1), a magnetic force is generated on the round or rectangular surface of the electromagnets, attracting the small intervention unit between the face of the electromagnets and the points of the hull of another ship, quayside infrastructure, or offshore installation, and the adjustment is made through a pivotal con-

necting element connecting the arms (4) to the body (1), then a rigid connection is made in a horizontal position to the waterline, followed by undocking by disconnecting the voltage supplied to the electromagnets (3), which loosens the connection between objects, and undocking of the floating unit from the points of the hull of another ship or column of quay-side infrastructure or offshore installation, while docking and undocking control is carried out by a powered control system equipped with inductive distance sensors, remotely controlling the electromagnetic field strength.

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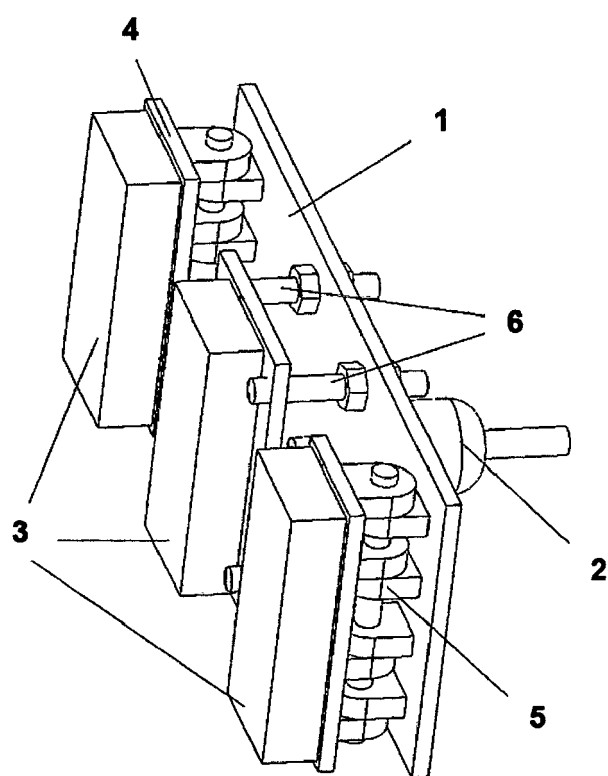


Fig. 1

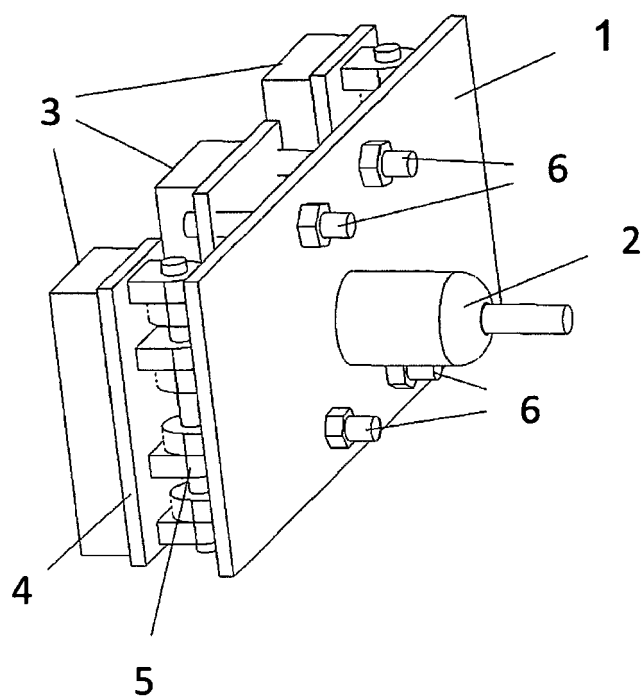


Fig. 2

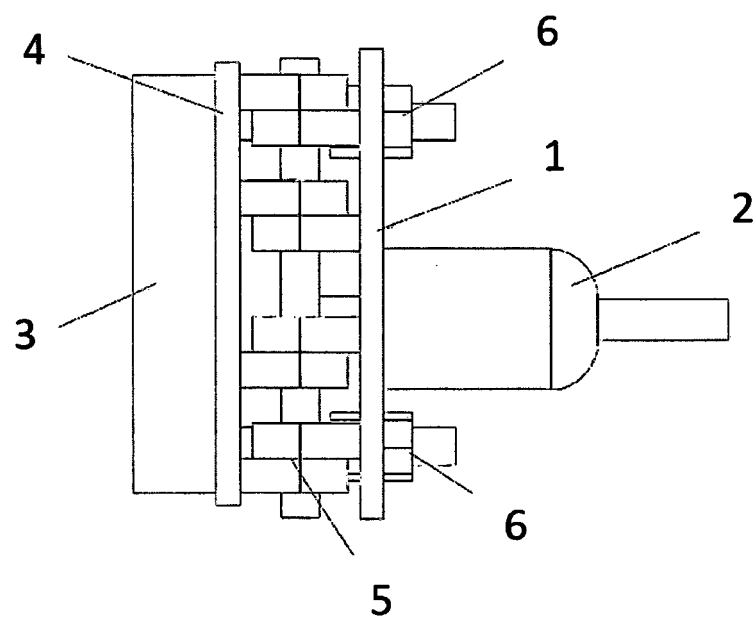


Fig. 3

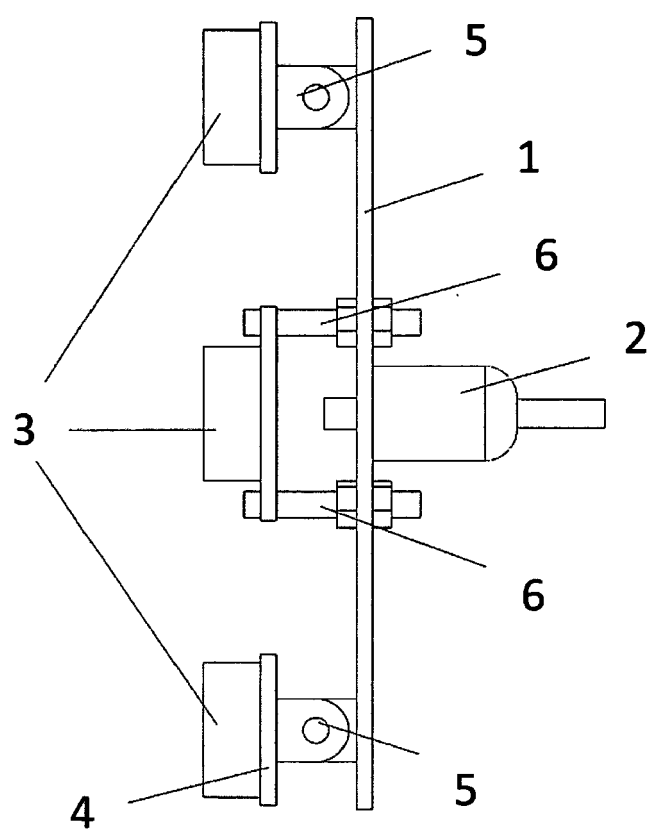


Fig. 4

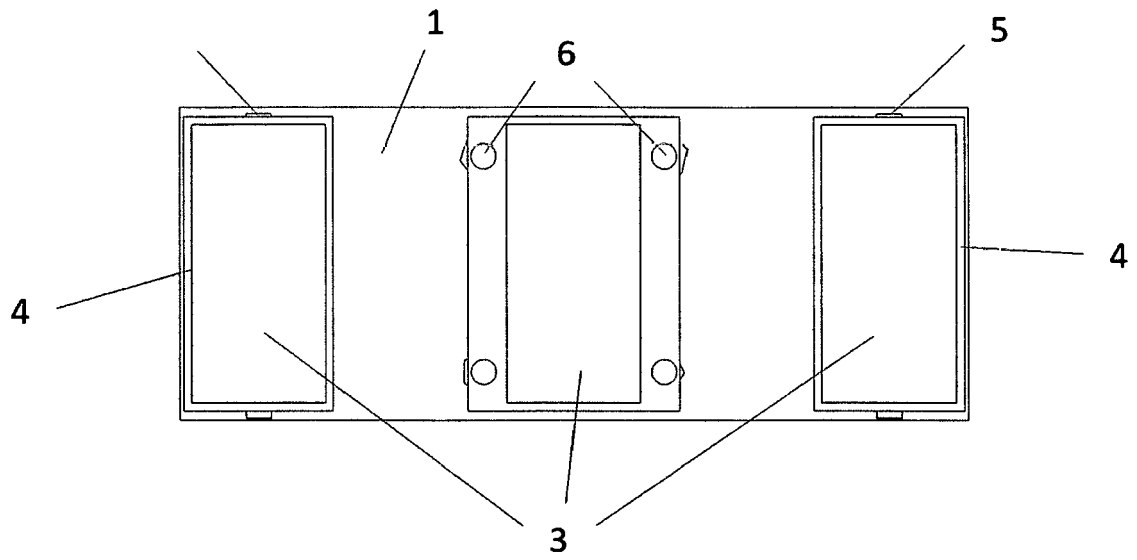


Fig. 5

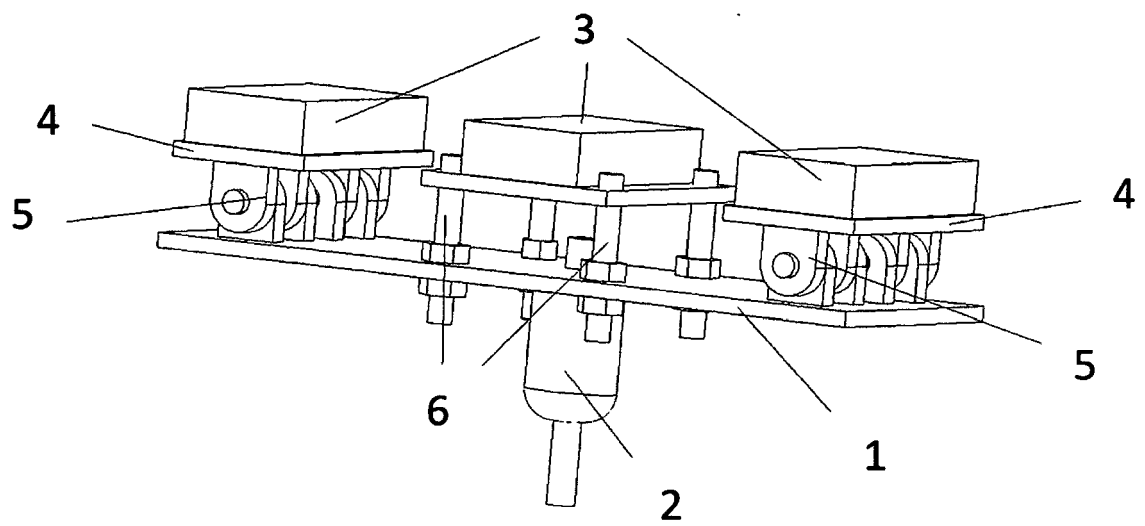


Fig. 6

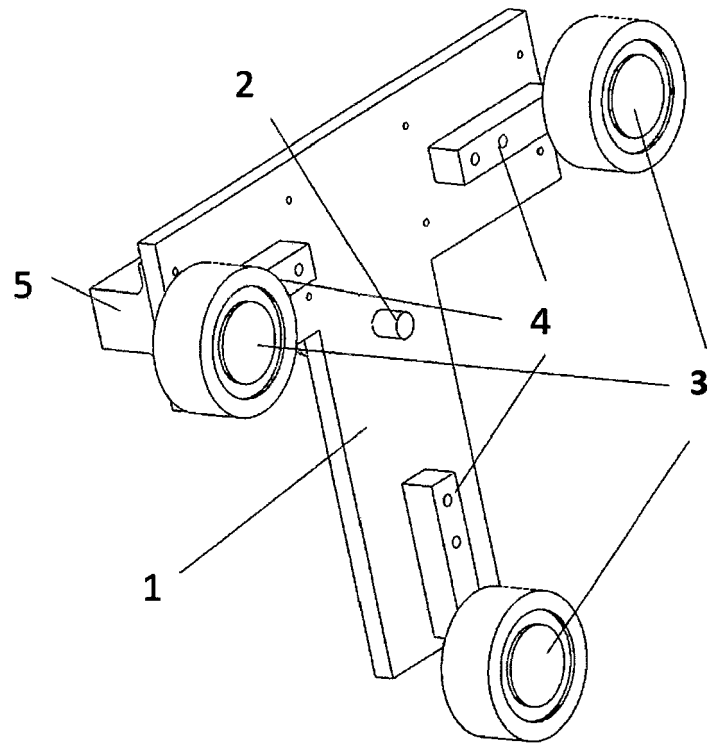


Fig. 7

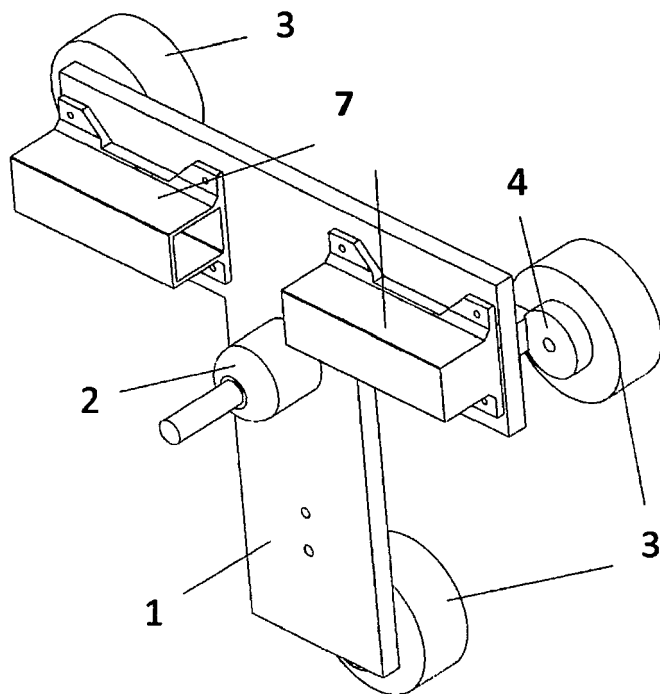


Fig. 8

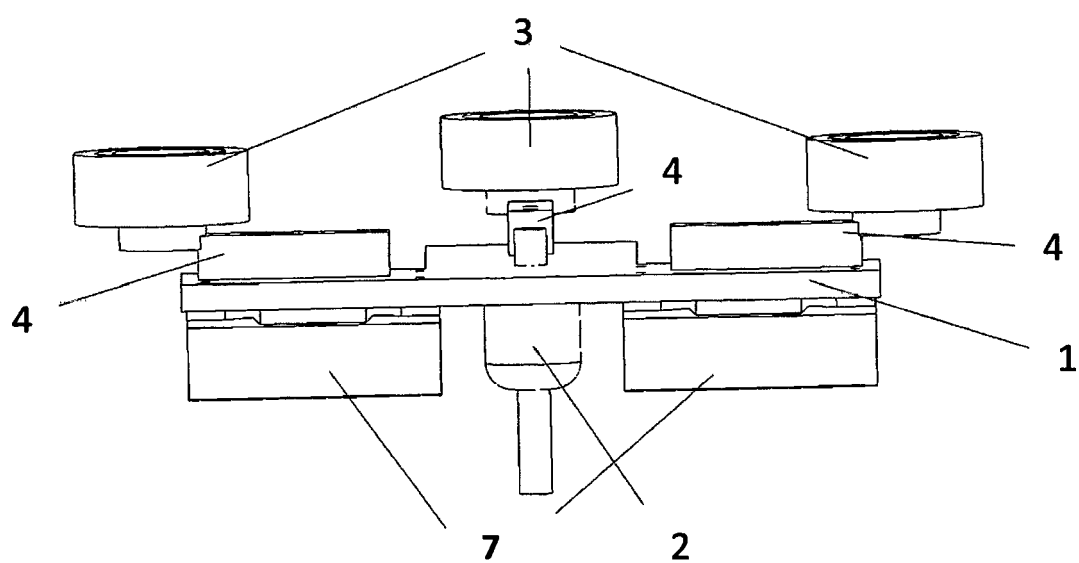


Fig. 9

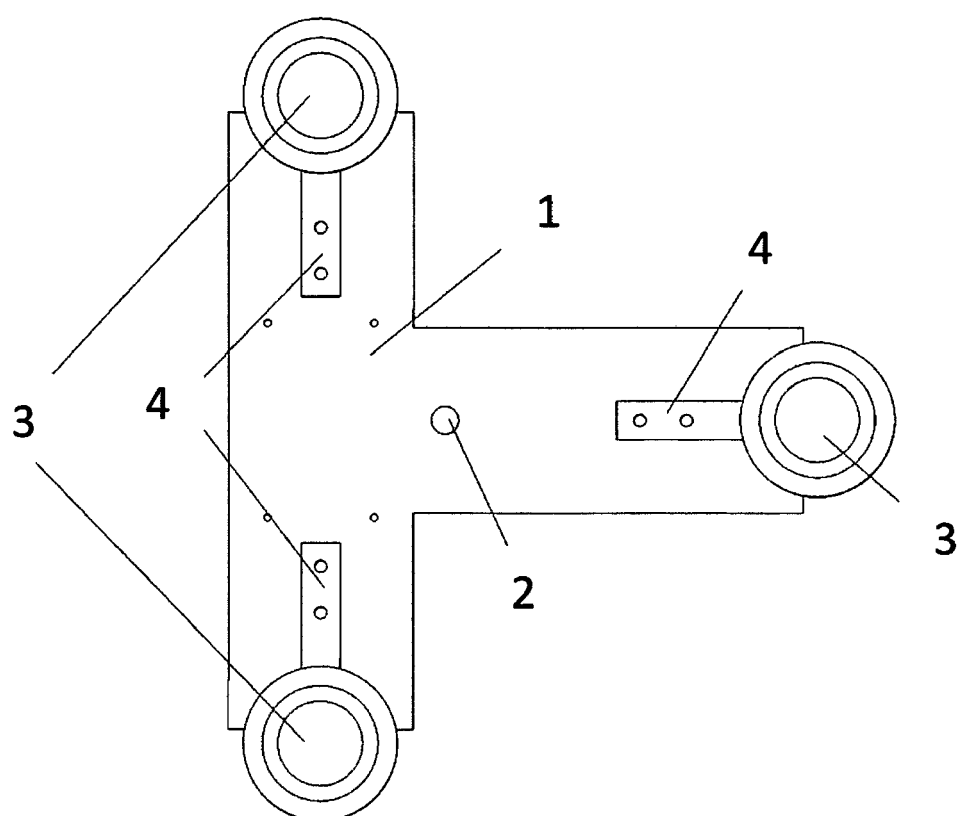


Fig. 10

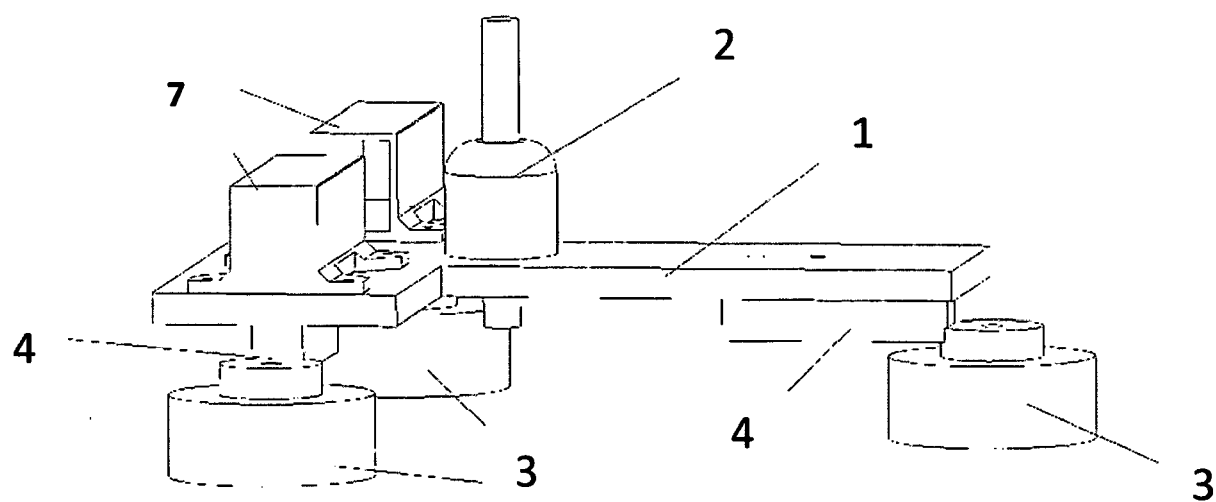


Fig. 11



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Place of search The Hague		Date of completion of the search 25 April 2024	Examiner Freire Gomez, Jon
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ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO.

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