USING INOVATIVE MAGNETIC MOORING SYSTEM TO IMPROVE SHIP SAFETY AND PORT EFFICIENCY

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Abstract

Mooring is a term used to denote the entire manoeuvre of ship approaching to a quay and securing her motionless to it. This process is one of the ship's most common operations, beginning and completing every one of her voyages. At the same time, it is also one of the most risky and dangerous activities, both on board the ship and on the pier. This is because the centuries-old traditional mooring system secures the ship to the pier by means of ropes or steel wires that are sent ashore and tightened. This method has resulted in numerous incidents causing damage to the vessel and/or the wharf, as well as personal injuries, often with fatal outcome. Recently have been developed modern innovative mooring systems which greatly improve the safety as well as the efficiency of the entire port stay of the ship. In addition, they have a positive effect on the area environment protection.

Keywords: *Mooring, electromagnetism, ship safety, environmental protection, port efficiency*

ИЗПОЛЗВАНЕ НА ИНОВАТИВНАТА МАГНИТНА СИСТЕМА ЗА ШВАРТОВАНЕ ЗА ПОДОБРЯВАНЕ БЕЗОПАСНОСТТА НА КОРАБА И ЕФЕКТИВНОСТТА НА ПРИСТАНИЩЕТО

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Резюме: *Швартоването е термин, с който се обозначава цялостната маневра по подхождане на кораба към кей и задържането му неподвижно към него. Този процес е една от най-често срещаните операции на кораба, с нея започва и завършва всяко плаване. В същото време е и една от най-рисковите и опасни дейности, както на борда на кораба, така и на кея. Това е така, защото съществуващата от векове традиционна система за швартоване осъществява задържането на кораба към кея чрез подадени на брега и натегнати въжета или стоманени проволки. Този метод е довел до многобройни инциденти, причинили повреди по кораба и/или кея, както и наранявания на хора, нерядко с фатален край. Има разработени съвременни системи за швартоване, които значително подобряват безопасността, както и ефективността на целият престой на кораба в пристанището. Освен това, те имат положителен ефект върху опазването на околната среда в района.*

Ключови думи: *Швартоване, електромагнетизъм, безопасност на кораба, опазване на околната среда*, *ефективност на пристанището*

1. Introduction

In order to load or discharge their cargo, ships have to be well and safe secured to the pier or terminal [5]. Mooring and unmooring are usually considered the culmination of a ship's activity, because they are where every voyage of the ship begins and ends. The term "mooring operation" includes various stages: approaching the quay, turning into the required position, securing the vessel with mooring lines and/or anchors, safely staying alongside during loading and unloading operations, and unmooring and departure from the port. The ship can be moored independently, most often for large ships this is assisted by harbor tugs, and each mooring operation is unique in itself, even repeated consequent moorings at one quay are never the same as the previous ones.

However, the safe mooring of ships in a port brings various economic benefits to the country [1]. It contributes to greater efficiency by reducing the time ships spend in port. Safe mooring of ships in ports is not merely a technical process but a key factor for stability and economic success. Investments in the safety and efficiency of this stage of maritime trade impact the overall economic development of the country [2, 3]. The existing traditional mooring operation is carried out with the help of a mooring gear, using mooring ropes, usually synthetic (nylon and polypropylene) or steel, as their size and number depend on the size and characteristics of the particular vessel. These mooring lines must be certified and also regularly inspected – if found to be in poor or damaged condition, they must be immediately replaced with new ones.

The traditional mooring system has two significant drawbacks:

- High risk of accidents

Despite all IMO's efforts, mooring is one of the most risky and dangerous activities, which has led to many accidents, putting both the crew on board the ship and the shore personnel at the wharf at risk. Unfortunately, these accidents quite often result in deaths, injuries and financial losses [1]. Statistics from the European Harbour Master's Committee (EHMC) show that of all recorded mooring injuries, 95% are caused by ropes and wires, and 60% of them occur during mooring process. According to the insurer UK P&I financial losses from major incidents during the period 1995-2016 (including injuries to seafarers, crews and port staff) caused by mooring equipment were reported to exceed US$34 million [8]. Ship berthing operations are highly dependent on human interaction and many accidents have their root cause in this fact. EMSA's review of investigated incidents over the period from 2014 to 2022 states that the average percentage of human influence as a contributing factor to these incidents occurring was 80.7% [4]. In most cases the main reasons are lack of mooring equipment maintenance, leading to equipment failures, untrained and inexperienced personnel, improper weather conditions assessment, poor communication, etc. The risk of accidents is also increased due to the large number of people involved in the ship's mooring process, both on board and ashore.

- Time consuming

Traditional mooring using ropes is time-consuming (sometimes more than an hour), as in order to berth the ship safely, usually a large number of quite heavy ropes have to be sent ashore, tightened and secured, all of this manually by crew and port personnel. Each mooring line requires time to be fed, held on the wharf, pulled from the ship and secured on deck. All this takes considerable time, which, of course, depends directly on the number of ropes. The mooring time is significantly increased if worsening weather conditions are expected because then more ropes than usual are used, as they must at all

times resist the forces caused by different factors (wind, currents and waves, interaction from passing vessels). Once the ship's mooring operation is completed, the crew's care of the ropes does not end. As a result of loading or unloading, the ship's draft changes, so the crew must constantly monitor their tension and adjust them if necessary - slack or tighten them, which also takes a significant part of their time. Same is if the ship is moored at port with significant tide phenomena.

2. Principle of magnetic mooring system

One of the ways to overcome the disadvantages of the traditional mooring system is the use of electromagnetic technology to establish an automated dock mooring device, for instance – a magnetic chuck. Beginning with the invention of the electromagnetic chuck by the American WALKER company at the end of the 19th century, it has gone through the stages of alnico permanent magnetic material chuck and electric permanent magnetic chuck, and then in recent years, the application of rare earth permanent magnet technology such as neodymium iron boron permanent magnets has made the electromagnetic chuck technology fast development [11].

The magnetic mooring system has a fixed dock installation, either with permanent magnets or using the system with electromagnetic on the pier or on floating pontoons, so it can go with the tidal movement. Electromagnets are temporary magnets which work on the magnetic effect of electric current. It has been found that if a soft iron rod called core is placed inside a solenoid, then the strength of the magnetic field becomes very large because the iron ore is magnetized by induction. This combination of a solenoid and a soft iron core is called an electromagnet; an electromagnet consists of a long coil of insulated copper wire wound on a soft iron core. The electromagnet acts as a magnet only as long as the current is flowing in the solenoid, the moment the current is switched off the solenoid is demagnetized [9].

As shown in Figure 1, the structure of the electromagnetic mooring device basically includes a pillar with strengthening structure (1), a shift support system (2), a buffer pressure-bearing system (3), an electromagnetic chuck (4), and a hydraulic adjustment system (5).

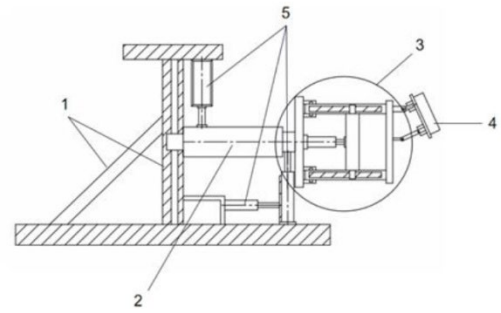

Fig.1. Schematic diagram of electromagnetic mooring device [11]

Fig.2. Electromagnetic mooring device in operation. [7]

The suction cup with combination of permanent and electro magnets usually consist of several chucks, which bring a perfect balance between their North and South poles and make all poles active. The advantage of this system is that it does not lose the magnetic force without electric power.

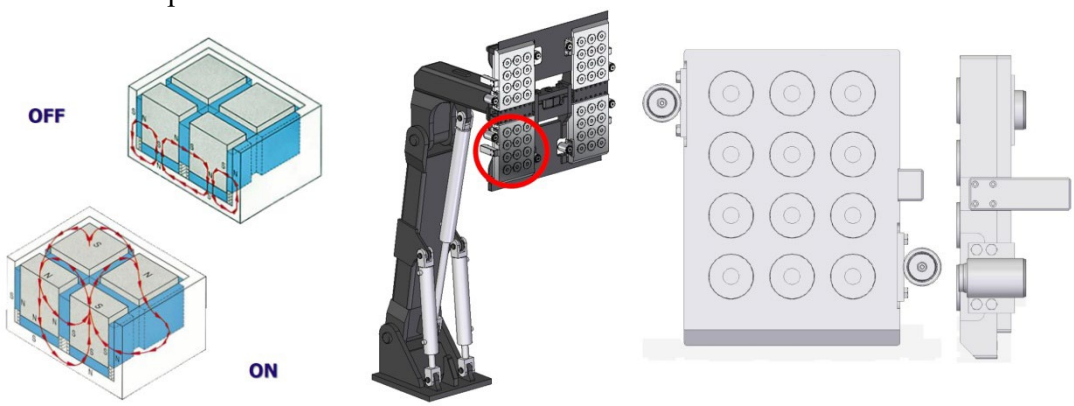

Fig.3. Combined magnetic mooring device. [10]

The basic principle of automatic magnetic mooring system operation is as follows. The ship is brought parallel to the pier at distance of a few meters. When the equipment is working, the shift support system extends the electromagnetic chucks (suction cup); the hydraulic system adjusts them to an appropriate height and position according to the position of the ship. When the electric power of the solenoid is switched on, the soft iron core creates strong magnetic field and generated electromagnetic force attaches the suction cup to the ship's hull. Then the ship is pulled towards the pier and secured in this way. During the berthing process of the ship, as the hull moves up and down due to rising and falling tides and ship loading and unloading, the hydraulic adjustment system continuously adjusts the displacement support system to ensure that the electromagnetic chuck is in the best working position. The pressure device can buffer the instantaneous impact force generated by the six-degree-of-freedom motion of the hull, and ensure the safety of the electromagnetic mooring device and the berth wall [11].

During the ship's port stay a data acquisition and analysis module is collecting real-time meteorological information (wind speed and direction, current speed and direction, tide height, etc) and ship dynamic information (pitch, roll, sway, surge, heave, draught change, etc.), processes it and sends it to the integrated control system. This system calculates the required suction force of the electromagnetic chuck and the location of the equipment, and

forms a dynamic and uninterrupted monitoring through the ship mooring auxiliary monitoring system to ensure the safety of the ship while alongside.

3. Characteristics of magnetic mooring system

3.1. Benefits of magnetic mooring system

- No risk of injuries. A magnetic system is much safer than a traditional system, which includes high casualty risks. When using magnetic mooring there is no more need for ropes so the risk of snapping and slipping ropes is eliminated.
- Almost every kind of vessel can be moored with the magnetic mooring system, no matter their size.
- Much faster mooring operations. Unlike the conventional system, using magnetic automated will berth the ship within several minutes, releasing the ship is for less than a minute.
- No need of big number of personnel involved in berthing/unberthing. It is just a one-button operation.
- Automatic control of ship's movement during entire port stay.
- Ecological impact. Fast berthing means less work on the ship's propulsion system (main engine, generators, and thrusters), tugs and mooring boats, and therefore reduces emissions into the port environment.
- The system can be used in ports with changes of water level due to the tide. There are always two pads that will work together. When the vessels draft or the tide will change the two pads have to work together – the pads will disconnect, move and connect again to the ship's hull, fully automatically.
- Increases the port efficiency – reduced time for berthing leads to faster commencement of cargo operations and finally to less time in port. This ensures faster turnaround, better ship utilization.

3.2. Disadvantages of magnetic mooring system

- The biggest disadvantage of the system is that if electrical blackout occurs, the current will not run through the copper wire anymore so the magnetism will be gone. In case of electrical failures the ship will be released from the magnetic chucks and this most probably will lead to an accident. It could be solved by connecting the electrical system to an emergency generator. So far while using magnetic mooring system, electrical failures have never happened and such accidents have never been registered.
- It is not possible for the system to move in a lateral way, so it is not possible to be used in ports with strong flood and ebb currents.
- Significant drawback could be the magnetic field, which can harm the ship's electrical installation and may have a big influence on the navigating equipment on board of the vessel and it can damage it. The strong electric magnet can even cause the ship to become an induced magnet. This field can even be that strong that it would be impossible to load and unload containers on a container vessel. One way to prevent magnetic field to damage other systems onboard is by using magnetic stop plate – an extra thick high-efficiency magnetic alloy plates, especially designed to provide superior shielding for electric circuit product [9].
- With the constant force, produced by a permanent magnet it is impossible to unmoor the vessel; it can perform the mooring but unmooring is impossible - possible solution is using of electromagnet.

- The thickness of the vessel's hull can be a problem. When the thickness of the ship's hull is less than 8 millimetres it is possible that the magnetic force can bend the ships' hull during mooring an unmooring, but every ship nowadays has a hull thicker than this, so it is not a real problem.
- Mooring tankers can be challenging because the system can cause an electrical spark. [6]

Conclusions

Conventional mooring can sometimes be extremely dangerous and usually takes a long time. It is an energy-intensive and labour-intensive process that requires the participation of the entire crew, as well as significant number of port personnel. Automatic magnetic mooring technology eliminates hazards and cuts mooring time literally to seconds. This allows port operators to reduce handling time, increase the number of ships handled and improve their economic performance. With this system, fuel consumption and harmful emissions are reduced; the time for using tugboats is limited. It automatically limits and controls the movement of the vessel while it is moored at the quay, resulting in greater productivity in loading and unloading operations. And as this technology continues to develop and improve, it is expected to play an increasingly important role in the future of shipping and could have a profound impact on the green shipping industry.

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