Automated Mooring for Ships

A PEMA Information Paper

This information paper provides an insight into the inherent risks of conventional mooring, and reviews how automated mooring and associated technologies reduce these risks, improve operational efficiency, and, according to manufacturers of such systems, reduce environmental impact.

Despite many aspects of port operations becoming increasingly automated in recent years, the mooring of ships remains, for the most part, un-automated. Mooring continues to be conducted using heavy mooring lines often handled by, or used close to ships' crews and shore side personnel, exposing them to bodily injuries, and in some cases, death, as well as causing damage to vessels and port equipment.

However, there are several automated mooring alternatives available today that offer port operators and shipping lines ways to moor ships more safely and efficiently.

PEMA
PORT EQUIPMENT MANUFACTURERS ASSOCIATION

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01.EXECUTIVE SUMMARY AND AIM

DOCUMENT PURPOSE

The mooring of ships has remained largely unchanged for thousands of years. This is despite the procedure posing considerable safety risks to personnel both on-board ships and on shore. Furthermore, costs in terms of damaged port equipment, infrastructure and operational delays result, many with associated insurance claims.

In recent years, several automated mooring technologies have emerged that offer port operators and shipping lines methods of securing ships safely and efficiently without the use of mooring lines. Furthermore, while not their primary purpose, these technologies generate environmental and operational benefits. The reduced time required for the mooring process using this technology reduces the pollution impact on the environment by both vessel engines and supporting vessel (tugs) engines when deployed. In addition to the benifit of improved air quality, automated mooring in combination with other technologies becomes an enabler for enhancining port automation.

This document does not set out to recommend any of the automated mooring technologies currently available on the market. Rather, it offers an insight into the risk factors associated with conventional mooring techniques, and how automated mooring technologies offer ways to address these issues.

ABOUT THIS DOCUMENT

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02.BACKGROUND

Ports are a fundamental component of global trade, with the vast majority of goods transported by sea. However, increases in vessel size, consolidation in the industry, and tightening regulatory requirements are placing growing demands on ports and shipping lines in terms of operational efficiency and safety respectively.

Automation is widely recognised as one effective answer to these challenges. Many port operations have been successfully automated, including cargo handling, passenger processing, and equipment monitoring. The basic principles of mooring ships have however remained broadly unchanged for thousands of years. Most mooring operations continue to be performed manually using mooring lines. Conventional mooring continues to be a safety risk to both ship and shore personnel, and a damage risk to ships, shore side equipment, and port infrastructure.

2.1 RISKS ASSOCIATED WITH CONVENTIONAL MOORING

Conventional mooring is vulnerable to a variety of human factors, enironment conditions and equipment failure. Human factors typically include: poor communication between personnel, fatigue, lack of training, experience and knowledge, recklessness, lack of, or poor observance of standard procedures. Equipment failures include worn-out lines and wires, and, for example, fairlead rollers rusted solid. Enironmental conditions include slippery surfaces, bad lightng, and a restricted view of mooring operatons,

According to a 2016 report published by the UK P&I Club, a leading maritime insurance organisation, key risk areas with conventional mooring "are predominantly related to procedures and practices with insufficiently trained crew "

2.2 HUMAN FACTORS

According to the report, the mooring incidents it studied were characterised by several reoccurring factors, including:

- Seafarers standing in bights or snap-back zones are injured when lines break
- Crews with insufficient training undertake mooring operations, (it is often inexperienced crew members who are seriously injured in mooring accidents)
- The person supervising a mooring operation is also involved with other tasks, making them unable to carry out their role effectively

2.3 EQUIPMENT FAILURE

According to another UK P&I Club report, "Understanding Mooring Incidents", published in January 2009, major accidents involving mooring equipment in the previous 20 years cost the organisation more than USD 34 million. Many of those accidents occurred during the handling of ropes or wires that separated (53 per cent), or where ropes or wires slipped off drum ends and bitts (42 per cent). Five per cent of these incidents were caused by actual equipment failure.

"Parted ropes and wires normally occur during general mooring, tug and ship to ship operations with equipment failure, misuse, wash damage and weather also playing a role. Injuries from non-parted ropes/wires normally occur due to crew being caught up in ropes/wires and ropes wires slipping off and becoming jammed on drum ends during normal mooring operations," the report states.

"Whilst mooring injuries are the seventh most frequent cause of personal injuries in the Club they are the third most expensive per claim indicating how horrific some of these injuries can become," it adds.

03.AUTOMATED MOORING – INTRODUCTION

Automated mooring systems offer significant benefits to port and ship operators in terms of berth efficiency that may not be evident upon initial review of such products. When compared to conventional mooring equipment such as bollards or quick-release hooks, when only the mooring of the vessel is taken into consideration, then the economics of operating an automated mooring system may not stack up, automated systems being several times more expensive than conventional equipment.

A more holistic view, based on a review of the entire product, procedures, including personnel transfer operation, which takes place at a particular berth must be taken. Automated mooring systems do not simply moor a vessel, they also ensure that the vessel has the appropriate mooring force at all times to restrain the vessel and reduce its motions whilst on the berth. Rope-based equipment without self-tensioning capability will allow mooring lines to slacken or over-tighten depending on the movement of the vessel resulting from external factors such as wind, short and long period waves, current and passing vessels. Typically mooring lines are not re-tensioned with frequent regularity by ship's crew, leading to snap-back of the lines in certain conditions, which can be a serious safety hazard to ship and shore-based personnel.

The constant tension feature of automated mooring systems bring the benefit of expanding the 'window of operation' for product transfers compared to conventional equipment. This results in increaed efficiency of the berth typically by up to a 90%+, when used continuously. This allows for the servicing of more vessels and ultimately increased profits for the port and ship operators.

In addition to the benefits of dealing with external conditions, fully-automated vacuum or electro-magnetic mooring systems can moor a vessel in less than a minute. This represents a significant operational time advantage over mooring lines which can take anything from 5-10 minutes for fast-turnaround vessels and up to a couple of hours for large vessels which are moored at exposed jetties. Less time to moor means faster product transfer operations resulting in less vessel time on the berth. This improves the berth's efficiency by possibly allowing another vessel to be included in the berth roster. Additionally, the fast mooring allows the vessels to leave the berth faster and can therefore cruise slower to the next port, saving fuel and reducing the environmental impact.

A further benefit of automated mooring is the systems' compact mooring arrangement. Conventional rope-based mooring arrangements are typically longer than the length of the vessel being moored in order to achieve optimal line angles for the bow and stern lines. Automated mooring systems have a compact mooring arrangement along the flat sided hull of the vessel. This means a port operator can accept a vessel which is longer than the berth allowing the bow and/or stern to overhang. As new-build ships are generally increasing in size, port infrastructure often struggles to keep up. The use of automated mooring systems can reduce the need to extend berths, which can be costly and time-consuming.

04.BENEFITS

4.1 SAFETY

None of the automated mooring technologies described above use conventional mooring lines. The removal of mooring lines from the mooring process dramatically improves the degree of safety with which ships are moored.

4.2 OPERATIONAL

The reduction in the amount of time spent mooring that these systems offer, and the improved effectiveness with which vessels are held in position along the quay, creates substantial operational efficiencies, particularly for bulk and container handling applications. In certain situations these systems also improve berth utilisation: vessels can be moored closer to each other as no additional space for mooring ropes is required on the quayside, and ships' bows can overhang the end of the quay.

4.3 INFRASTRUCTURE

Automated mooring ensures safe mooring even during adverse weather conditions which can create heavy swell. This in turn potentially reduces breakwater construction requirements.

Since automated mooring systems usually "attach" to vessels within the ships profile, shorter berths are possible, and special mooring structures are not required, resulting in further infrastructure cost savings.

4.4 ENVIRONMENTAL

Automated mooring significantly reduces the amount of time tugs are required to moor vessels. The amount of time varies depending on which automated system is used. For example, the use of automated mooring in container handling applications generates reductions in emissions from tugs of more than 90 per cent of the total emissions compared to conventional mooring.

Furthermore, the improvement in the effectiveness and accuracy of mooring made possible by automated technologies substantially reduces the likelihood of ships having to be moved along the quay once moored. This reduces emissions further while increasing operational efficiency. Equally important is the fact that the shorter turn-around time allows the vessels to leave the berth faster and cruise slower to their next port of call, thereby reducing fuel consumption and emissions.

The use of automated mooring has also enabled the implementation of electric vessels. One of the key issues electric vessels face, especially ferries with tight schedules, is the need to maximize the charging time while they are at the quay. By automating the mooring process, the vessel can be in a secured position quickly and with repeatability. This allows the charging connection to be automated, made earlier and removed later. This allows the vessel designer to reduce the battery size needed to support operation as charging time is maximized through the day.

05.AUTOMATED MOORING ALTERNATIVES

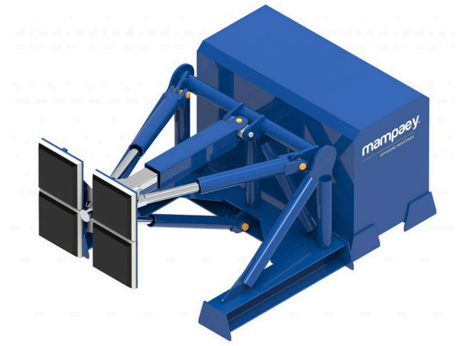
5.1 VACUUM MOORING

Vacuum mooring employs remotely controlled vacuum pads mounted on or integrated into the quayside that moor ships in around 25 to 40 seconds. This compares to up to one hour with conventional mooring. The units hold vessels securely in place alongside, and detach in less than 15 seconds.

The technology has been in use since the 90s and has been installed at bulk, container handling, Ro/Ro, passenger and lock applications worldwide. At date of this publication, vacuum mooring installations have completed more than 750,000 mooring operations entirely without incident, including the regular mooring of 19,000-TEU vessels.

5.2 MAGNETIC MOORING

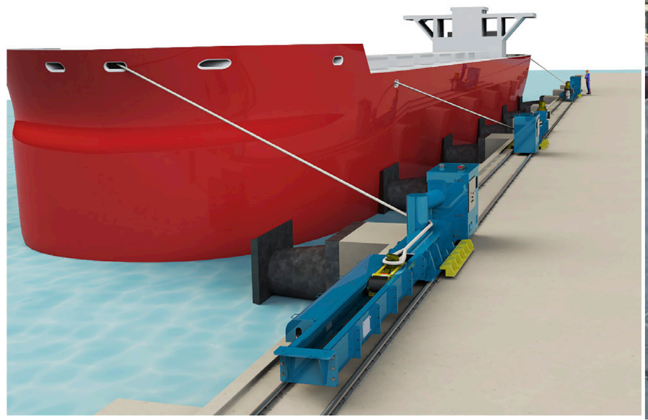
Magnetic mooring employs magnetic technology rather than vacuum pads to moor and hold vessels in place. Initially conceived as a ship-ship system, the technology is currently in use in ferry applications to provide ship-to-shore mooring.



5.3 SEMI-AUTOMATED MOORING

There are two versions of semi-automated mooring systems: one that is hook-based, the other winch-based. The hook or grip-based version consists of a vertical guiding mechanism that attaches to the ship. The ship needs to be fitted with a bollard to which the hook can be attached. A recess to accomodate the bollard must be built into the side of the ship.

Vessel modifications are required for semi-automated units that employ a winch-based systems to secure ships in place.



06.SIZING AND SELECTION

6.1 VESSEL SIZE, POSITION AND HULL CONDITION

Maximum vessel size and positioning of vessels along the quay wall are of paramount importance when sizing an automated or semi-automated mooring system. The impact of these factors varies for each system.

VESSEL SIZE / LENGTH

DWT and vessel length play a critical role in sizing an automated system as these variables will greatly impact the work the mooring systems must perform to maintain vessel stability. It is also important to note the available freeboard as well as the flat length along the side of the vessel. Automated mooring systems are designed to attach to the flat side of a vessel and not along the curved bow and stern sections. The system density must be designed to hold the vessel only along this area.

VESSEL QUAY POSITION

The port operator has multiple options on how a mooring system may be deployed along a quay wall. The first option is to create berth systems where designated vessel sizes only use specific berths. This of course is dictated by harbour conditions and quay equipment (i.e. STS crane height/reach). In this scenario, an automated mooring system would be specifically spaced and designed to suit berth by berth. The second option is to have mooring units spaced evenly along the quay wall giving maximum vessel position flexibility to the port operator. This also allows vessels to overhang the quay end as the automated systems only require the flat side of the vessel for attachment.

HULL CONDITION

Though less prevalent in container vessels, poor hull condition will impact on the efficiency of the units. If there are frequent visits of vessels with poor hulls, the number of units deployed may need to increase to counteract this decreased efficiency as well as provide further redundancy. This limitation does not apply to semi-automated systems as these are still rope based.

6.2 WEATHER AND TIDAL CONDITIONS

As with rope and bollard design, the number of automated and/or semi-automated mooring systems must be sized to accommodate the environmental conditions a vessel may experience while on the berth. Compatibality with the existing infrastructure must be considered in the cases of brownfield projects.

WIND

Average wind direction and speed are critical factors in sizing an automated mooring system. Combined with the size of vessel that will use a berth, the forces associated withsway and surge which the system will experience is one of the force factors that must be taken into account when selecting the number and spacing of units.

WAVE AND PASSING SHIP EFFECTS

Various wave conditions may impact the specification of a mooring system. Some ports experience what is known as "long wave" conditions that cause severe movement in vessels while moored which significantly reduces productivity. Long waves (also known as infra gravity waves) are characterized by long periods between waves. These waves carry higher energy levels and thus impact the moored vessels significantly. These forces must be taken into account when sizing, the number of units as well as control methods for dampening motion due to severe swell.

For severe conditons, a combinaton of automated and semi-automated mooring systems may be optmal.

Passing ship effects also create water forces on the vessel while moored as the wake impacts the vessel side causing movement. These effects are frequently found in high traffic inner harbours where vessels frequently pass closely to moored vessels during loading/unloading operations. Again, the impact is the same. To decrease the vessel movement and increase productivity, the mooring system must be sized to take these forces into account.

TIDAL VARIATION

Whereas tidal variations may impose only minor forces on the system itself, the change in tide level, especially if significant, may require the positioning of the units to account for the severe changes. On a conventional port application the units are typically berth mounted on the surface or plinth. For ports where there are both large draft and tidal changes, a face mounted installation may be required to allow the system to follow the vessel through its motion while berthed. Though this is typically a bulk carrier scenario (severe draft changes as well as tide), there are some container ports globally that may experience this challenge.

6.3 QUAY CONDITIONS

In a perfect world all the conditions necessary for the installation of new technologies at a port either during greenfield construction or upgrading a brownfield site would exist. However this is not the case as each quay/berth brings its own challenges to sizing and installing an automated mooring system.

QUAY CONDITION / DESIGN

For both greenfield and brownfield installations, the concrete construction of the quay itself must be taken into account when selecting both number of units and unit density. Both the concrete material and reinforcing bar positioning/density will impact on the strength available over a specific area of quay wall. Mooring systems differ in their civil loading from bollards as the forces applied to the quay wall are typically located closer to the quay water edge. However, the trade-off is that the forces are distributed over a larger area and evenly. The quay must be capable of resisting these new force vectors.

RAIL LOCATION

The challenge many ports face is lack of space between the water side crane rail and the quay edge. This is the space where an automated or semi-automated mooring system is generally installed. When this space becomes too restrictive various measures must be taken to allow the installation of the equipment. Some options include placing the units on an overhanging plinth to ensure the the installation does not interfere with the rail and crane leg. Another option is to position the units on the berth face. However, this creates further challenges that must be addressed such as new loading on the quay structure as well as fender size and spacing. Newer compact units are now on the market from a number of manufacturers where some of the semi-automated solutions fit nicely along the quay edge. However, this space will vary sinificantly from port to port and is one of the main considerations during installation design.

FENDER SPACING/SIZING

As the units must be able to extend and hold onto the vessel side, the fender design is critical for the sizing and installation of automated mooring units. In combination with the rail location factors, fender depth, especially when fully compressed, may limit the overhang used by mooring units to counteract the lack of quay space. One solution is to install spacers between the fender base and quay to allow greater depth while the fender is at full compression thus keeping the mooring unit out of harm's way. Spacing of fenders along the quay length will play a role in positioning of the units as the units must be placed between fenders even while mounted on the berth surface. This spacing becomes more critical when considering face mounted solutions as the fender gaps will limit installation width and structural availability.

07.COMPLIMENTARY TECHNOLOGIES

Automated mooring can be a solution in itself, but it is also a prerequisite for disruptive changes to the maritime industry at large as it provides functionality that can improve the performance of other related systems.

7.1 TERMINAL AUTOMATION

Looking ahead, automated mooring is an integral part of a fully autonomous maritime supply chain, where ships sail, moor, and load/un-load by themselves. Today, mooring is the missing link between an ever more automated terminal and the increasingly technologically advanced ships. By automating the mooring process a large step towards a future where cargo is moved without any direct human intervention is realised. Additionally, the greater vessel stability that certain automated mooring systems enable will also facilitate the full automation of related activities such as container movements.

Thanks to advanced sensing capabilities certain automated mooring systems also provide valuable information related to the status of the mooring, vessel and even the environment at large. The more advanced systems can measure all the forces that they are exerting on the vessel as well as the position, thereby enabling exact measurement of the environmental conditions and their impact on the system.

7.2 AUTOMATED VESSEL CHARGING

Since many automated mooring systems enable fast and stable positioning relative to the shore, they are commonly used together with (automated) power supply systems. The fast connection to clean power reduces emissions and increases the charging time for electrical vessels. The higher vessel stability simplifies the technical requirements of the connection solution, making it safer and more efficient.

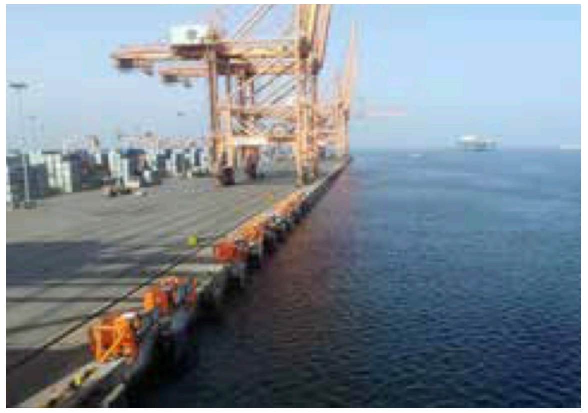
7.3 RADAR VESSEL SENSING

Radar technology is a new alternative for docking assistance systems and can be used to aid in positioning the vessel for automated mooring. The use of radar is considered preferable to laser systems. Radar is more robust for typical marine environmental conditions such as mist, rain, fog and even ice and snow. Since radar does not measure only one extreme small point (as with laser), scattering effects or absorption are not an issue while maintaining the precision required for vessel positioning duties. The radar solution can also provide distance and speed of the docking vessel. 2D radar sensors are also available, which provide a full vessel scan.

08.EXAMPLE INSTALLATIONS

8.1 PORT OF SALALAH

Key installation drivers: Long wave (Khareef season)



Port of Salalah in Oman experiences significant long wave impact during the monsoon season (Khareef season). To counteract these long wave effects, automated mooring systems were installed to dampen vessel movement while berthed. With the automated mooring system installed, it allowed the port operator to continue full loading/unloading operations even during the most severe long wave conditions while maintaining high efficiency.

8.2 PORT HEDLAND

Key installation drivers: Passing ship effects, high tidal variation

Though a bulk carrier port, Port Hedland faced multiple challenges during operations. Both passing ship effects and high tides changes impacted the feasibility and efficiency of loading operations at the port. This required the automated mooring units to be installed on the wharf face and on rails to fully follow the ship during draft and tide changes. This is especially critical for this application due to the extended time the vessels spend at berth during loading.

8.3 PORT OF BEIRUT

Key installation drivers: Wave induced motion at an unprotected berth, narrow space between rail and berth face

Having determined that it would be economically unviable to extend the existing breakwater to protect a new 500m quay extension, the Port of Beirut needed a solution to mitigate wave-induced vessel motion at the unprotected berth. By using an automated mooring system, the port was able to mitigate these effects. The units are face mounted on the quay with slim line power units to ensure fitment between rail and berth face. Also, the units are positioned on either side of the fender to ensure the units are protected from vessel impact.

09.CONCLUSIONS

While conventional mooring continues to be widely used at ports and terminals all over the world it represents a genuine risk to personal health and safety, port equipment and infrastructure, and results in considerable human and financial costs for individuals and the industry.

Through the toal removal of mooring lines from the mooring process, automated mooring offers the industry a way to reduce the risk of serious injury or even death of personnel. In addition, and to varying degrees, the automated mooring technologies now available also offer operational, infrastructure, and environmental benefits.

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11.ABOUT THE AUTHORS & PEMA

ABOUT THE AUTHORS

This paper has been prepared by Jim Andriotis of the Cavotec Group with assistance from PEMA member companies..

ABOUT PEMA

Founded in late 2004, PEMA's mission is to provide a forum and public voice for the global port equipment and technology sectors, reflecting their critical role in enabling safe, secure, sustainable and productive ports, and thereby supporting world maritime trade. Chief among the aims of the Association is to provide a forum for the exchange of views on trends in the design, manufacture and operation of port equipment and technology worldwide.

PEMA also aims to promote and support the global role of the equipment and technology industries, by raising awareness with media, customers and other stakeholders; forging relations with other port industry associations and bodies; and contributing to best practice initiatives.

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Suppliers of technology that interfaces with or controls the operation of port equipment

Consultants in port and equipment design, specification and operations.

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