

**ROBOTIC SYSTEM TO LOCATE, IDENTIFY AND ENGAGE INTER-BOX
CONNECTORS (IBC) IN A CONTAINER TRANSFER SEQUENCE**

TECHNICAL FIELD

The subject matter relates to the shipping industry and the sub-field of handling sequences that includes the installation or removal of inter-box connectors (IBC). Hereby disclosed is an electro-mechanical stevedoring robot system (a combination of a multi axis industrial robot, a mechanical end effector, optical indexing means with memory storage and a multitude of physical storage means for keeping IBC) that can locate, identify, and engage ISO standard freight containers and attached IBC.

BACKGROUND ART

With reference to the subject of this application, Cameron Hay, PCT/SG2007/000444; Kapelski, US 7779604 and our earlier application PCT/SG2005/000279 have all suggested an 'intermediate step' of utilizing a cradle (a purpose built structure) that is to be a transit / support point for the purpose of carrying out automated fixing and removal of IBC, the said cradle being accepted as a significant contribution to improvement to workplace safety. All these documents have suggested in slightly different ways, the need to scale down the use of physical labour in this field with a strong focus on occupational safety. However, heavy investments cannot be justified by marginal / restricted projected results as commerce undoubtedly uses a cost vs benefit approach for implementation purposes, and therefore the rate of handling containers must be considered a primary concern that is close, if not on par with safety of personnel. In consideration of the prior art, the simplest embodiment of the present invention is a self sufficient electro - mechanical alternative for one human operative typically assigned to carry out said works. Therefore, this invention affords the divisibility of large and rigid machinery found in the prior art into simple and effective standalone operative cells and offers alternative highly flexible deployment of automation for container ports to maximize benefits from technology. Of particular note is the highly hazardous environment besides the typically frenzied activity of container port operations, where the automation of as many procedures of the work as possible, is obviously desirable.

In container vessel berthing operations, containers (and therefore IBC) cannot practically be positioned (without slowing down normal flow of operations by unacceptably slow movement of the machinery involved) in an exact spot within a space

of dimensions less than 600m x 600m (plan view), without the use of a cradle with sloped sides. The lack of precision as normally required for mechanized automation is bridged by the said indexing component included in the present invention, thus negating the need for a purpose built intermediate cradle or other structure to position the IBC

5 beyond positioning means afforded by a transport machine (eg. a truck) which is a necessity anyway, in the relevant field of application. Bypassing the intermediate cradle, it is still sufficient to make use of existing lateral transport means (eg. the currently popular corner-less chassis prime mover (CCPM) or equivalent machine such as Automated Guided Vehicles (AGV) to transport containers between the yard and the

10 docking wharf) to function as a platform for automated (mechanized) IBC fixing / removal. Automated operations as such are achieved by either an autonomous single robotic cell or a collective station of a few such cells that each employs an industrial robot to handle IBC, with broad indexing means (additional to earlier said 'sharp' indexing to seek out the IBC placed within practical limits) coupled with cheap and

15 traditional methods such as road humps and traffic lights to guide a truck and the driver respectively. The use of this invention will streamline container operations and reduce wharf congestion, and in the overall (in combination with CCPM) reduce the absolute number of lifting tasks, thus speeding up operations, reducing costs and also contributing to a safer workplace. The preferred embodiment of the present invention,

20 deployable as a port automated system is a collection of said single robotic cells which can be customized into automated twist-lock handling stations that can be isolated as depicted in *Fig. 1* from the container vessel berths or situated according to the peculiar arrangement of a given port. Variations in port setting can be due to traffic volume, port infrastructure and preferred method of deployment. Varying needs of individual ports

25 can employ this invention in different configurations as depicted by the variations in Figures 1, 2 and 3.

The invention, either as a single cell or a station of multiple cells, while best suited to CCPM operations can also be adapted to suit other systems such as buffer cranes and

30 straddle carrier operations. The invention can also be fitted to quay cranes (as in Fig. 4), spreaders and transportation equipment such as trailers and straddle carriers. Incremental automation, remote stations, portable stations adapted to multi lifting setups such as double spreader and four spreader operations are also possible. The robotic arm fitted to a CCPM is depicted in Fig. 5. The mounting of the invention on quay crane

35 spreaders can further critically impact upon berthing operations as the robotic systems

can also perform the on board action necessary to discharge containers. This is an especially qualitative use of the technology to be beneficially exploited in berthing operations, otherwise stevedores have to perform the task of unlocking the twist-locks while dangerously positioned on container top at heights normally exceeding 10 metres.

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As said earlier, accurate positioning of the container on trucks (even with mechanical guides such as humps or troughs to help the driver position the vehicle) is likely to present a challenge. It is necessary to include indexing devices that seek out the target within a narrowed (by eg. humps) space range. Present embodiment of the indexing system relies on the standard geometric features offered by ISO standard container corner castings depicted in Fig. 6. Other means of indexing such as the use of magnetism, mechanical sensors or sonic means can also achieve the desired capture of the container position that is necessary to feedback to the multi-axis robotic arm to then transport the end effector to the necessary location accurately. Future embodiments of this technology that is similar to scanning distinctive features of targets can also detect variations in heat, presence of radiation, chemical leakages and damages to the container. As such the opportunity is offered for the inclusion of such capabilities in the remote twist-lock station as envisaged by the inventors.

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The end effector (Fig.7) currently works with separate devices for respectively, gripping the twist-lock by the bottom neck (which universally conforms to ISO corner casting dimensions), and twisting the bottom cone of the twist-lock which inserts into the top corner casting slot of the container below. Given the separate devices used in combination, plus the ability of the indexing device to read the geometric features of the twist-lock, the invention can also pick up twist-locks placed in an unplanned orientation (eg. from a heap in a bin normally used by the vessel owner to store them).

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It is also possible to integrate the clamping and twisting functions into one device (such as a pneumatic rotary actuator) by the use of cam profiles included onto the clamping parts that get compressed as the mating features attached to the rotary actuator acts on the relevant profile of the clamping parts as the rotary actuator twists the bottom cone.

It must also be noted that the present embodiment was designed with a view to include interchangeable end effectors to suit different model twist-locks, as is the situation with container handling operations.

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SUMMARY OF PRESENT INVENTION

The preferred embodiment of the invention assumes the preference for the use of CCPM over traditional two – step loading / discharge cycle for which a cradle system is prescribed by the prior art citations. The involvement of a cradle would mean
5 predetermined positions of corner fittings upon placement of freight container on said cradle, thereafter mechanical arms or spring loaded systems proceeding with their tasks in predetermined rigid fashion. Having justified the need for more efficient management of time and assets, this application suggests bypassing the intermediate step of placement onto a cradle by, direct placement onto transport vehicles and automation of
10 the location, identification and engagement of IBC by employing a robotic station that does all the said 3 tasks in a matter of seconds by employing a set of sensors in individual actuation arms. The robotics employed in this aspect of yard operations, not only stands in for the stevedores, but is also able to observe and identify the random nature of the relevant variables and automatically prescribe itself, an appropriate action
15 that is to be executed next, based on a combination of analog and digital readings and calculations. The sensors can be based on infrared, sound detection, light detection, heat detection or image capture and identification technology that combine to function with the known geometric configuration of ISO freight containers.

20 CCPM were designed as such, to accommodate their cargo with the corner fittings exposed for access by human operatives to either install twist locks upon the container (for loading onto the vessel) or to remove twist locks (during vessel discharging operations). The investment already made on this mode of transport is substantial. The introduction of direct receipt sequence from quay cranes will further optimise the
25 investment if a given yard is working with excess capacity, as the hourly rate of the quay crane increases - referring to the absolute number of containers handled - coupled with the robotic system handling the twist-locks. A yard already working at optimum level employing the cradle system will experience a higher optimum level if it makes a switch to this non-cradle sequence and applies the said robotic features.

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The innovative inclusion of recognition technology enables the familiar multi-axis industrial robot to be deployed as a remote robotic station that automates IBC handling in operations involving CCPM. The CCPMs, upon receiving freight containers from the lifting machines (eg. quay cranes, straddle carriers, container forklifts) allow IBC
35 operations (either by automated means or by 'hand') independent of lifting machine

involvement. This is of critical value for port operators especially where it concerns the quay crane as the CCPM allow the dedication of the quay crane spreader to only the loading and discharging of the container vessel thus speeding up the quay crane cycle by far. Cradle based systems of the prior art, while implying a safer working environment, also demand a proportionate regression to the working speed of pre-CCPM days as they are not compatible with CCPM. Given the highly dangerous nature of dock work (especially involving the installation and removal of IBC amidst large moving machines), it is inevitable that the human operative is gradually phased out in favour of automated means of handling IBC. However, all devices of the prior art have to date failed to keep pace with the fast improving (in operational speed terms) lifting technology which all ports are heavily investing into. The present invention ideally complements the use of CCPM, which is a clear advantage over traditional two – step loading / discharge cycles. The use of CCPM is unlikely to be given up by major ports that have invested heavily in them. The different dimensions of individual vehicles, the different models, the different modes (AGV or CCPM), tyre sizes, non-level ground, and individual driver error can, in total, pose a vast combination of corner fitting positions that require a machine to sense these variations when the ‘ human stevedore ‘ is phased out for safety reasons.

Yet another benefit of employing the invention described by this application is the transfer of substantial work away from the docking area that contribute to neat and organised dock operations. Once the CCPM are loaded they would immediately proceed out of the docking area which will definitely contribute to transshipment hubs that are experiencing space constraints due to rapidly growing international trade. The subsequent tasks applicable to each container's sequence movement will be transferred to lower expense equipments like straddle carriers which do not incur berthing charges for the ship and in turn allow the port to handle an increased number of vessels in a given day. The application of this invention increases productivity by increasing the rate of turnover and attaining lower costs from multiple aspects as for the port and the vessel owner and yet also having stepped up to provide and maintain a safer workplace.

DETAILED DESCRIPTION OF THE PREFERRED EMOBODIMENTS

The first embodiment of our present invention would be defined as a fixed station as suggested by the arrangement as in Fig. 1, situated in an isolated position away from

the busy wharf area that is also optimal to serve high capacity berths. The robotic arms described by our application would feature as posts that are situated at ground level (that can be a permanent fixture (Fig. 1) or temporarily anchored (Fig. 3) to suit the port operators decision), and the said posts being movable on a rail structure as defined in my earlier application PCT/SG2005/000279 to allow for both 20ft and 40ft containers, separated adequately in a parallel order to allow the CCPM to drive thru permitting an allowance on both sides of a minimum 1.5 metres for the unobstructed passage of CCPM and the said allowance to be utilised by the robotic arms that require such an operating radius (radius not limited to stated value). The said arms are to be at a retracted position (the orientation coinciding with the graphic used in the legend of Figs. 1, 2 and 3) in the absence of a vehicle in the station and will move into action only when a vehicle has positioned itself and the said vehicle is completely halted, and the said 'complete halt' condition to be translated to the robotic cell and the said translation to function as an electronic switch. Vehicle moving in and out of station can be controlled by well known methods as employed by traffic lights.

The electronic sensors (infrared light) would have identified the presence of a container as the CCPM rolls into the station by identifying the corrugated nature of the walls, and the shape and size and distance of the container corner casting. In the event of specialised containers that employ only a canvas cover the robot will signal the overseeing personnel for a human instruction. Upon detecting a container or getting a human input indicating the presence of a container, the robotic arm seeks by electronic means (infrared distance sensors and image capture technology) to zero in on the location of the corner casting of the subjected container and starts to resolve the relevant 3 axes (x, y, z) required for placement or detachment of IBC.

The 3 axes (or positioning) relevant to the other 3 corner castings can be determined in a default mode, by readings taken at a single corner casting or it can switch to an alternative second mode when necessary, to share the readings taken at the other 3 corner castings to arrive at a confirmation of the exact positioning of the container when irregularities compared to well known geometry of ISO containers are detected by the robotic cell.

One of the factors that can give rise to a wrong reading when using distant sensors is the accumulated damage suffered by the relevant scan area of the corner casting. A

substantial dent in the aiming point of a distance sensor can delay the transmission of a correct reading. The system employed by our preferred embodiment goes a step further to select a second position to confirm an unstable reading. An unstable reading can be flagged by the system, indicating a need for confirmation and an instruction to its own guidance software to, match and relate, for example, with the readings taken of a diagonally opposite corner casting in relation to a given first corner casting that turns out an unstable reading or produces a reading which does not fit into the known geometry of the ISO container or the set-up of robotic station as a whole.

10 The matter described in the preceding paragraph does not limit us to employing any particular electronic gadget but, it is proof that human labour as an input can be substituted by utilising suitable electronic sensors in conjunction with the speed of a computer's calculation to successfully replace the speed and flexibility of human mind and body.

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At present quay cranes, vessels and port operations' centralised system communicate between themselves by electronic means to work in concert with regard to the freight manifest. The introduction of electronics into yet another aspect of port operations and the availability of image capture and recognition devices can be extended to communicate with quay cranes if required.

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The said remote station can be a separate 'hangar' type of building or it can be portable to be fitted into urgent high intensity situations like double spreader or quad spreader operations. As such the robotic system so configured can be portable to be pressed into service where and when required by trailers or forklifts. This is made possible by the weatherproof construction of the system with additional provisions to withstand the marine environment.

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