# Research and development of automatic bulk cargo equipment in modern ports: Part 1

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This paper describes research and development into automatic grab ship unloaders, automatic loading machines, and automatic bucket stackers and reclaimers for bulk cargo in the Port of Shanghai, which have been integrated with a multitude of advanced technologies, such as long-range detection, computer networks, automatic control, and intelligent decision-making etc. With the above integration, efficient automatic bulk loading and unloading can be implemented in the port, along with achieving management and control integration of automated operations creatively, and establishing a solid foundation for building fully automatic bulk cargo terminals.

This paper introduces bulk grab ship unloaders and automatic and fully automatic bulk loading bucket wheel stacker-reclaimers, jointly developed by Shanghai Port, Shanghai Port Machinery Plant, ABB (China) and Shanghai Jiao Tong University. The study involves a number of key technologies, such as the outline of the long-distance materials detection, computer network, automatic control, intelligent decision-making, grab anti-sway, path planning, video surveillance, and remote monitoring equipment, all implemented in order to achieve a high-performance when handling automatically, stacking and remote monitoring bulk cargo.

## Background

With the development of economic globalisation, the capacity of bulk cargo, especially ore and coal, is growing. In 2007, dry bulk throughput in Chinese ports was 3,565 billion tonnes, an increase of 13.5 per cent in 2006. It is expected that in the next three years, throughput growth of dry bulk cargo will reach 13 per cent. The proportion of dry bulk cargo throughput at the Port of Shanghai is more than 40 per cent and still rising.

Presently, both at home and abroad, most bulk cargo is manually handled by handling equipment and operational efficiency and security is entirely dependent on the driver's proficiency. Some terminal areas are also equipped with semi-automatic controlled handling equipment, that is, the main parameters are controlled manually, so that higher efficiency and reliability can be achieved.

In order to adapt to today's trends of providing professional, large-scale and high-performance handling equipment, most countries in the world are vigorously studying the applications of information technology and automated and intelligent technology in order to build or upgrade their bulk cargo terminals. Development of new types of bulk cargo handling and distribution equipment, as well as bulk cargo operation management and control systems, will enhance a port's core competitiveness.

## Facilities

### Automatic grab ship unloaders for bulk cargo

Unloaders operate in two existing ways: manual and semi-automatic mode. Efficient manual shipment is entirely dependent on the driver's proficiency, which can easily alter the swinging motion of the grab, thus human factors can result in instability in the efficiency of operations. The semi-automatic mode has two shortcomings: on the one hand, drivers must constantly manually set and update operating parameters, as operations have poor ability to adapt, and there is a big security risk. In particular, due to hold materials, as well as changes in the fluctuation of the tide, the hull is susceptible to floating or tilting, thus using a semi-automatic mode to unload ships runs the risk of the grab colliding with the ship. On the other hand, owing to the irregular distribution of bulk materials inside the hold, the driver must still manually set the return point on the top of the hold for the next cycle when starting the automatic circle, in order to achieve optimum unloading and avoid grasping air or grasping a small bucket etc. For the above reasons, both automatic operation and manual adjustment are both difficult to coordinate.

On the basis of existing manual and semi-automatic functions, automatic grab ship unloaders for bulk cargo (Figure 1) are

Figure 1. Automatic grab ship unloader for bulk cargo.

equipped with hold and materials scanning system (here referred to as a TPS), to automatically detect hold location and distribution, replacing the driver's need to manual setup operations, and bringing into realisation, continuous ship unloading, and improvement in operational efficiency and performance safety.

In the unloader's automation programme, the use of a TPS sensor has three main functions: detecting cabin location, materials distribution and return location. The TPS is installed at the front of the cab platform.

The automatic unloader uses laser ranging detection technology to achieve automatic detection and identification of a number of objectives including ship location, hold location, bilge and hatch and the height of the hold, as well as the types and distribution of materials.

Hold location and the height of the bilge and hatch determine the regional border of shipment operations. Whether the regional operating area is appropriate or not is directly related to the security of shipment process. If the cabin location and the height of bilge and hatch are not correct, grab collision will easily happen. On the other hand, taking security into consideration, the operations area needs to be reduced, but this will also reduce shipment efficiency.

Discharging strategy is based on materials distribution in the hold. At the same time, the system needs to determine grab position according to the height of the materials. An incorrect height determination will lead to the phenomenon of a grab being less than full, the air grasping and buried in fighting, which will reduce operating efficiency, operational disruption and even cause accidents.

During unloading, ship positioning will change with water and wind, ship height will change with the tidal fluctuations, the materials distribution inside the ship will change with the shipment operations, the movement and the collapse of bulk cargo will lead to changes in materials distribution inside the hold. Shipping location and materials distribution have no fixed rules. The return point of the grab depends on the accuracy of the automatic identification system.

## Automatic loading machines for bulk cargo

Shipping operations are currently using manual methods, with the scope of shipping operations and the various shipping sports bodies being controlled by the driver through the console. At present, the main problem in the loading process is that the loading machine's cabin is found at the top of the boom, blocking the driver's sight so that he cannot observe the slip off of the tube and the materials distribution at the bottom of the boom. From this vantage point it is difficult to observe the tilt of the hull and difficult to accurately position the tube slide. Automatic loading machines increase hold detection, traffic detection, materials detection and video surveillance functions, along with providing real-time monitoring shipping operations and control procedures to ensure smooth and uniform loading operations are completed.

Automatic loading machines have the function of hold detection, materials flow detection, materials detection and video surveillance functions, which can face different types of ships and material surfaces during continuous operations, planning shipment paths automatically and effectively, as well as reducing the dust, noise and vibration at material transfer points, ensure smooth loading operation.

Automatic loading machines use sensors to detect the relative location between the hold and the loading machines (Figure 2), as well as the actual distribution of materials inside the hold. These are necessary conditions for accurate positioning, achieving uniform loading, and increasing the operating efficiency. According to the process of loading and the structural features of loading machines, automatic loading systems use two vertical laser radars as detection equipment to detect, identify and deal with the operations hold and reactor, to load automatically by controlling the movement of wandering extinguishers and large carts.

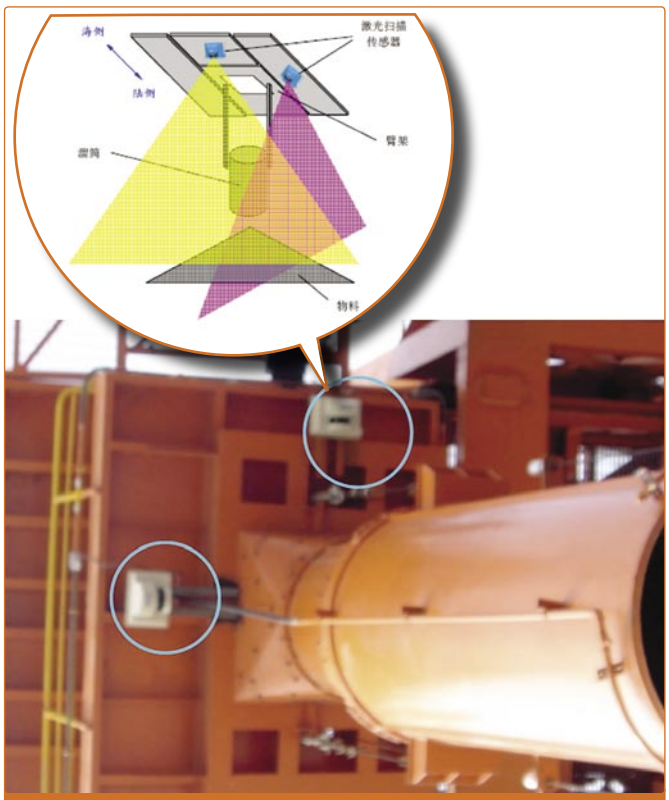


Figure 2. Diagram and view from below of auto-loading machine laser and radar detection system.

During evenly distributed automated loading operations the movements of the shipment agencies are adjusted in a timely manner in accordance with belt flow in order to enhance the efficiency of shipping operations. Therefore, accurate and real-time flow detection and shipping operations are closely related with its efficiency and safety.

There are two methods for flow control: one is to use the current scale of the belt installed on the belt-boom. Practice has proved that the no-load belt-current fluctuations lead to a calculation error of volatility of current flow. Another method is to use the transfer station on the ground belt for the corresponding shipment of the belt scales. A short time after the belt scales have been read, the materials will begin flowing through the tube. Practice has proved that this method measures a smaller error. Combining these two methods, automatic loading machines use a flow testing programme combining in-belt weighing machine belts and the shipment of the current detect according to the terminal site design, along with characteristics of shipping operations.

## Automatic bucket stackers and reclaimers for bulk cargo

In the current process, there are three main considerations concerning bucket stackers:

1) **Height requirements for operations:** In stack operations, materials need to piled high and flat in order to effectively use yard space and enhance storage capacity. In reclaimer operations, bucket wheels are required to be as close as possible to the bottom of the check so as to reduce the amount of materials bulldozers need to clear. If the height is inaccurately estimated by drivers, the bucket wheel will too easily shovel to the ground and cause an accident.
2) In the stacker operation, the driver's intensity of labour will increase because he has to focus on all parts of the bucket stacker and reclaimer.
3) **Influence on the efficiency of the process:** The loading and unloading process of most bulk cargo terminals requires bucket wheel stackers when conducting joint operations. On the premise

of a large-scale shipment and ship unloader, the bucket wheel stacker is often the cause of bottlenecks in bulk cargo terminals.

At present, foreign ports, such as Mexico, Germany and Japan have begun applying a bulk yard automation system. ABB (China) in Baoshan Iron and the Steel Majishan Port Phase II Project have both conducted bucket wheel stacker machine automation tests. The objectives of the automatic bucket wheel stacker we studied are to detect the changes in surface materials and plan an intelligent path in real-time.

As a detection device, the TPS system installed on the top of bucket wheel stacker can, in real-time, scan the reactor materials on the yard, and three-dimensionally reconstruct and calculate the reactor parameters, as well as control the bucket wheel to automatically stack. The TPS installations are located at the top of the vertical beam of the stacker and reclaimer, and aligned the cantilever. TPS can be installed on the bracket with active angle. Through the hinge or jointing, the bracket is fixed in the middle of the vertical beam. The scanning window is at the cantilever and the level and direction have a certain angle. A maintenance platform at the top of the vertical beam is set for debugging and maintenance.

To adjust the cantilever and pitching rotation angle, lift the bucket wheel to the highest position, and the cantilever of bucket stacker and reclaimer needs to be aimed at the scanned material pile. In a full scanning process, the TPS can read the data of the material pile when the cart drives through it at a uniform speed along the track. The scanned data will produce a new information model for the material pile in the database, or update the old information material pile model.

TPS adopted the two-dimensional high-speed scanning system. X, Y direction of the scan are -30 ° ~ +30 °. After crane expected reactor, it finish a scan every pitch, TPS conducted a scan, the largest spacing in accordance with the installation of the height of the TPS set. The TPS Scanning Region and Scanning Path are shown in Figure 3.

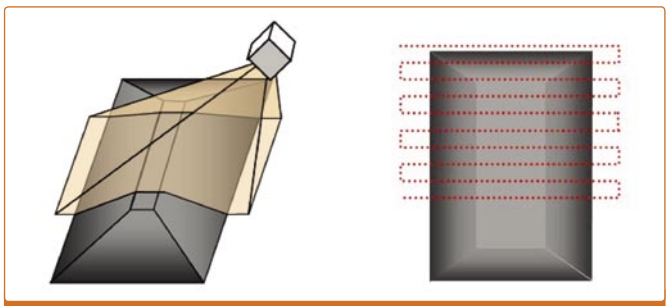

Figure 3. Stacker-Reclaimer TPS Scanning Region and Scanning Path

The pile data scanned by the TPS is in three-dimensional coordinates within a certain region. When the stacker and reclaimer move a certain distance, the TPS scans the region again. These two regions have a certain extent of overlap which needs to match the coordinates of two groups of data. We use the overall coordinates matching algorithm by making the endpoint of the track of stacker and reclaimer as the coordinates origin, the position encoder measures the current location when the crane moves, then converts the local coordinates of each scanned points into the overall coordinates. The data in the overlapping area is processed by covering methods, that is, for the point in the same direction of the Z, replacing the previous outline points by the scanned outline points. This algorithm is characterised by a small amount of computation, and data updating is very quick, shown in Figure 4.

*End of Part 1. Part 2 will focus on key technologies and methods involved in automated bulk operations including contour detection technology, materials distribution testing, optimisation of ship unloading strategy, fixed-point ship unloading, balance ship unloading, continuous ship unloading, and automation equipment operations followed by a brief summary.*

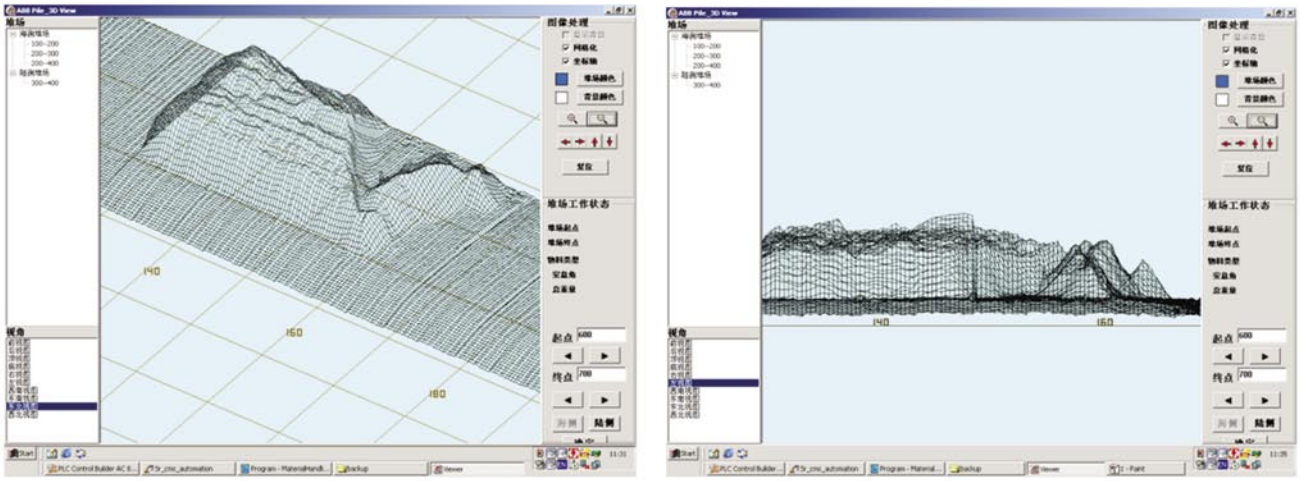

Figure 4. Stacker-Reclaimer stockpile outline (North-East view and view from left).

## ABOUT THE AUTHOR AND THE COMPANY

**Bao Qifan**, Professional Senior Engineer, Vice President of Shanghai International Port (Group) Co., Ltd. During his work experience, he has lead his S&T team to actively conduct self-innovation and integrated innovation, and to apply digitaliation, intellectualisation and informationalisation on continuously updating the core competitions of Shanghai Port. Since 1981, Mr. Bao Qifan and his colleagues have successively finished more than 120 S&T projects in which they were awarded three State Invention Medals, three State S&T Advancement Medals, eighteen S&T Advancement Medals at Ministry or Province levels, and twenty-four Gold Medals in International Invention Fairs held in Paris, Geneva, USA, Brussels and etc.

**Shanghai International Port (Group) Co., Ltd.**, is the exclusive operator of all public terminals in the Port of Shanghai. Incorporated in January 2003 by reorganising the former Shanghai Port Authority, SIPG is a large-scale business conglomerate specialised in the operation of port and related businesses.

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