ADVANCES IN CONTAINER CRANES AUTOMATION

[1]Alojz Slutej, [2]Fetah Kolonić
ABB Ind. Systems AB; University of Zagreb, Faculty of El. Eng and Computing
S-721 67 Västerås, Sweden; HR-10000 Zagreb, Croatia
alojz.slutej@se.abb.com; fetah.kolonic@fer.hr

Abstract. This paper summarizes the most important advances of the used crane control technology in perspective of automatic operation of container cranes. Faster and more productive container cranes demands highly efficient yard system. Storage capacity is the limitation for most terminals today; automatic operation offers optimum stacking density and peak capacity equivalent for continuous manning of every crane. As cranes become larger and faster, operations starting to be increasingly more difficult. To meet the increased demand, different automation strategies should be adopted. Automatic operation requires sensor systems for target position (TPS), sensors for load position (LPS), video equipment on spreader/crane, control and communication equipment on the crane and remote consoles for video and control signals. As new large containers terminals are being built in many places, automation as already accepted technology with proven benefits, helping the change in mindsets towards increased acceptance of automation concepts.

Keywords: sensors, load position system, target position system, automatic guided vehicle, crane control system, sway control, skew control.

1. INTRODUCTION

As global trade continues to increase there is a steadily growing worldwide demand for container handling capability at the lowest possible price. Competition is sharpening as new container terminals are being built using the latest technology and existing terminals consider ways to increase their capacity while decreasing their cost, [1]. Not only is the total volume of annually shipped containers growing but so is also vessel sizes and the number of containers handled in a single port of call. Whether a large new terminal with massive automated yard handling capacity or a smaller terminal trying to keep up with competition, they all have the same strong incentives to improve the operational performance of the STS (Ship To Shore) cranes in their terminals. To meet the increased demand in quay crane capacity, different strategies can be adopted using a larger number of cranes or more complex crane designs such as dual trolley or dual hoist cranes. For all types of mechanical crane designs automation features can be implemented to increase a crane's productivity and decrease its operational cost further. Even though there are evidently strong incentives for improved STS Crane productivity and automation concepts can be used to achieve these goals, there has been widespread resistance against fully adopting the concept of automation in the crane business. Automation features have been perceived by some as too complex and by others as resisted among the crane operators since there is something in the notion of automation inherently conflicting with their professional pride. However, as STS automation has been around for quite some time by now and as terminals adopting automated rail mounted gantry cranes as their choice for yard container handling bear witness of the proven large scale productivity gains due to automation, the general view is changing. Confidence in crane automation is growing as the concept is gaining a more widespread understanding and acceptance. Terminals actually using their STS automation features indicate that with the implementation of proper operational policies and providing the right incentives for operators and maintenance personnel STS automation can successfully be implemented to increase the overall operational performance of a terminal. The rapid developments in areas such as sensor technology promise that the future will see a continuing development in crane automation systems.

2. CRANES AUTOMATION SYSTEM

Requirements of modern containers cranes result in demand for sophisticated crane control automation systems and reliable connection to the customer overriding information systems. These systems continuously provide up-dated information about containers moves and crane status.
To achieve an efficient and profitable modern container terminal design overall, following sequence should be applied:

- Select the optimum capacity for the terminal
- Select the most efficient terminal concept
- Select economical civil works design
- Select an economical crane concept and
- Automate

Applied automation should consider follows:

- Reliability/quality – breakdowns are costly in automated terminals
- Serviceability, support and diagnostics
- Flexibility – capability to handle present and future environment, vehicles, container types, operation principles etc.
- Simplicity- not more equipment than needed
- Safety – present and executed future safety standards

- Standardization and experience

Over the years, the frontier of container crane automation in terminals has been pushing worldwide and a wide range of products and systems for the automation of both STS and yard handling RMG (Rubber Mounted Gantry) cranes has developed.

2.1. Ship to Shore (STS) transportation system automation

As cranes become larger and faster, operations become increasingly more difficult. The greater distance from the operator's cabin to the vessel deck impairs visibility and reduces the level of detail for the operator. Faster motor speeds, shorter ramp times and longer ropes make it even more difficult to control spreader movements. There are several ways to aid the operator. One is to assist in the difficult stages; another is to relieve him of some of the work so that he can give his full attention to the more difficult tasks. ABB offers a complete range of automation building blocks for mixing and matching into a crane system to assist the operator in the best possible manner. With combined and position control, movement between quay and ship or vice versa can be fully automated, with the operator only supervising, [2, 3]. If there is a connection between the crane and the terminal operating system, work orders with predetermined destinations can be sent to the crane. Once an operator accepts a work order, the production cycle is performed automatically.

When the hoist reaches a safe height above a ship or the ground, the operator takes over and performs the landing. A skew control system corrects any unwanted skew pendulum movement caused by wind or unevenly loaded containers. Uncontrolled skew movement often becomes visible at the end of a production cycle, when the operator attempts to lower the spreader into the ship cells or when landing a container over the quay. Skew movement is difficult for an operator to control and can result in loss of valuable seconds each times it occur. Over time, these seconds add up and will affect overall productivity. With a skew control system, the time spent waiting for skew to dampen will significantly decrease. Over the quay, there are systems for aligning and positioning chassis, straddle carriers and AGVs. For example, a chassis alignment system can guide the truck driver to the correct position. Once the truck is there, the exact position of the truck or container is used as reference for the position and skew control system, ensuring that the spreader is in the optimum position for a pick-up or set-down. The positioning and measurement system, in combination with skew control and position control, speed up the landing cycle and minimise lost time due to wrongly positioned containers, chassis or AGVs. Cranes equipped with the latest features, such as double hoists or double trolleys, will benefit even more from the supporting systems. These cranes offer high potential capacity, but also require a well-integrated terminal process. The time saved due to extra capacity is easily lost when trying to line up chassis, dampen skew or when positioning head blocks.

2.2. Yard Automation

Faster and more productive ship-to-shore cranes also demand highly efficient yard systems. Fully automatic stacking cranes are essential in an efficient material handling system. For ABB, fully automatic stacking cranes no longer represent new technology; the technology is now well proven. Because automatic stacking cranes are faster, have higher ground utilisation and require less maintenance than traditional rubber-tired gantry cranes, they are well suited for loading and unloading the vessels of tomorrow.

For yard Automation several concepts have been introduced and they are presently employed around the world. In the following, a comparison will be made between two handling concepts that can be employed when the available yard area is limited and high stacking needs to be introduced. Another parameter that is becoming more and more important is the reduction of emissions from diesel engines.

For automatic cantilever RMG (Rail Mounted Gantry) cranes, container transfer in and out from the stack is made alongside each other. The area in which automatic operation takes place is fenced in, while controlled access to this area is made via card operated gates. All movements within the yard area and above a certain height over the travel lanes are performed fully automatically.

RFID (Radio Frequency Identification) readers can be located at the lane entrance in order to check truck/chassis identity. When loading/unloading manned vehicles the last part of the operation is conducted under the supervision of operators which are located in a remote office. An operator can handle four to six cranes. Cantilever RMGs can be made with very large spans and stacking heights and can be moved along the rails over several stacks but cannot be moved from one row of stacks to the next. The crane length is larger than that of an RTG (Rubber Tiered Gantry) because the containers have to be lifted between its legs.

RTG crane is one of the most commonly used vehicles for yard stacking and needs no further introduction. Each vehicle is manned with a driver; house-keeping is limited since the ability to move a loaded container in gantry direction is limited. The RTG can be moved between different stacks in the terminal. Modern RTGs are equipped with positioning systems, (e.g. auto-steering, DGPS and cameras are being introduced in some places in order to improve the driver's overview).

By choosing to combine these products and systems in different ways, an STS Crane can be equipped to a varying degree with automatic features to aid the crane operator in achieving productivity benefits while still maintaining control and responsibility over the crane in every situation.

The automation of STS cranes is sometimes referred to as semi-automatic since a crane operator is always present to supervise the automatic motion and to handle the parts of the job sequence requiring manual operation such as for example pick up and set down on the vessel. Over the world crane automation has been applied to regular STS cranes as well as dual trolley cranes and soon the world's first automated dual hoist STS cranes will be in production.

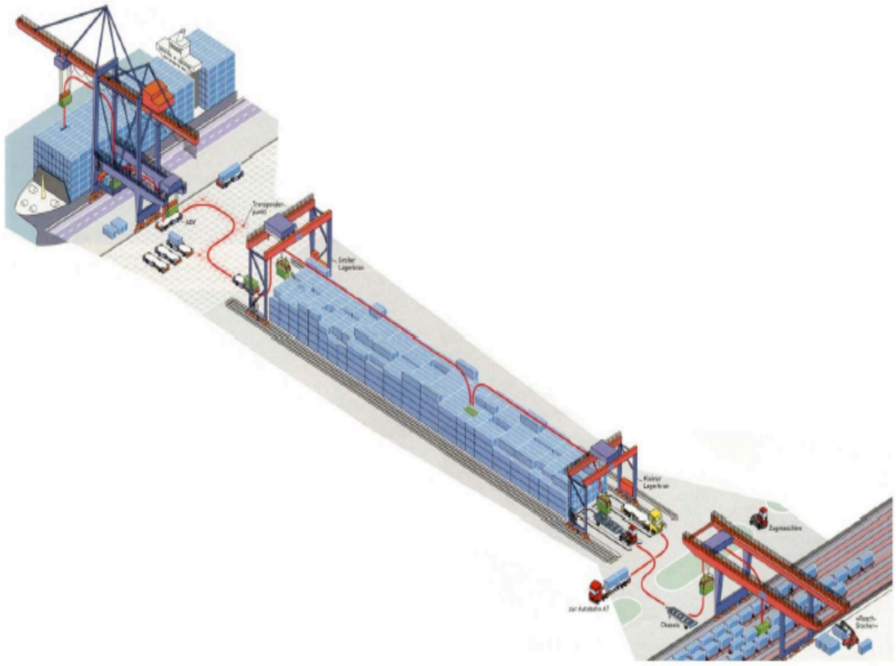

Fig.1. Crane automation process in harbour container terminal

3. AUTOMATION TECHNOLOGY

The typical automation product portfolio includes a series of optional products that can be combined freely to create a suitable automation solution for any needs.

Electronic Load Control (ELC) provide sway free manual operation of the load by means of Sway Control and automated travel cycles between any selected positions on vessel and quay following an optimal safe path and accurate positioning at the target by means of Position Control, Fig.2.

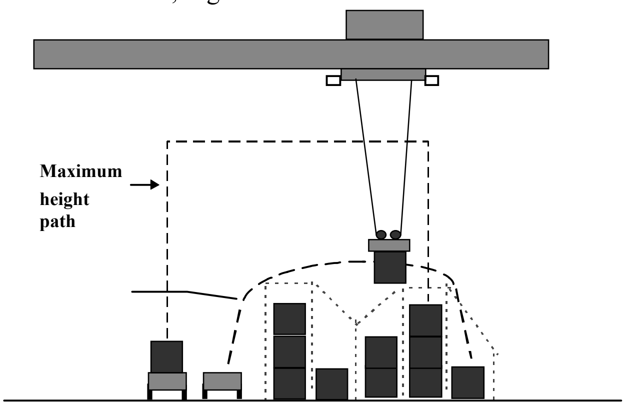

Fig.2. Optimum path for container crane positioning system

The Ship Profile System (SPS) is a laser based ship scanning system generating a height profile of a vessel for use in providing the optimum safe path for the ELC. By enabling main hoist smart slowdowns and trolley obstacle avoidance over the ship, the SPS guarantees fast and safe container handling over the vessel.
The Skew Control speeds up the landing sequence on both vessel and quay by minimising the skew motion of the load and controlling the skew angle to a given reference.

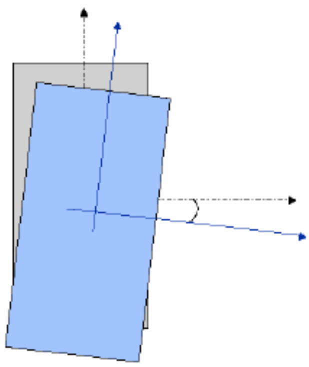

Fig.3. Skew control, basic principal

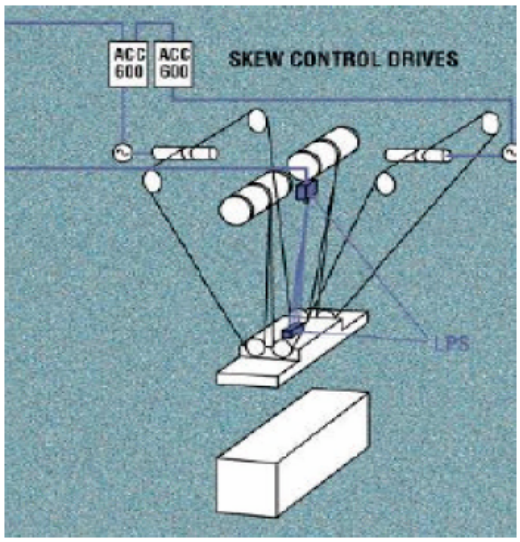

Fig.3. Skew control, realisation with corresponding drives

Skew pendulum is usually induced by unevenly distributed load, the wind or by mistakes during landing.

The Chassis Alignment System (CAS) guides the terminal chassis to stop in a proper position aligned to the crane enabling faster loading and unloading cycles, [4]. The chassis driver is guided by means of traffic lights mounted on the crane. The chassis position is measured by laser and CAS can be used with ELC and Skew Control to provide an accurate target reference for automatic positioning to speed up landings even further

Automated Container Landing System (ACLAS) allows the crane to perform fully automatic cycles from ship to quay by performing fast and safe automatic landings independent of the crane operator skill. ACLAS use ELC, CAS and Skew Control, [4], [5], [6] and [7].

When provided with *Terminal Logistics Control Interface* (TLCI), the crane is connected to the terminal logistics control system and thus further integrated into the terminal. Scheduling of work can be sent directly to the crane by giving the control system direct work orders to pick up or set down a container in a given position. Such work orders are then executed by the crane operator either manually or by starting and supervising the automatic job cycle.

The Spreader Control is related to the crane which is connected to a terminal logistics control system and is being sent work orders that are executed by the crane operator. The information in each work order is used to automatically operate spreader telescope, flippers and twistlocks.
The unmanned *Crane's Control Systems* (CCS) supports basic and advance application function. In order to achieve a number of different possibilities to solve engineered problems, the crane control concept includes:

- Powerful process controller with advanced multitasking, capable of handling several real time critical control loops simultaneously;
- High speed communication links between different clients;
- Advanced sensors technology for accurate measurement and fast transmission of positions and speeds;
- Centralized interface for diagnostics of the complete system.

Crane control system includes a wide range of well-proven solutions (including hardware and software) that are divided into blocks for easy adaptation to each client's specification. The control functions are standardized and built up around a basic core that is adapted on a project-to-project basis with add-on blocks. Usually, control system with its software specially developed for cranes, coordinates the entire crane functionality and communicates with, remote I/Os, drive system, information stations and crane automation sensors.
With ships and cranes becoming increasingly larger, it is imperative to use *Simulator assistance* in order to prepare crane operators in advance so as to achieve maximum productivity, and without compromising safety or failing to meet new work environmental challenges. Instead of taking cranes out of production and risking physical damage, customer can use a realistic in-house simulator to bring your operators safely up to speed. Using the ship-to-shore crane simulator, ports have experienced the importance and benefits of operator training on simulators, with on-crane training time decreasing by 40 to 60 percent after only three days on the simulator.
What is unique about the advanced simulator is its incorporation of the latest technology, with state-of-the art, real-time physics simulation and advanced 3D graphics, which enable training in exceptionally life-like situations. Moreover, the training strategy enables customers to turn out trained operators with a high degree of conformity, due to the disposition of predefined scenarios, with trainees following a path from basic crane operation to advanced operation.
The Crane Driver Training Package contains a 'full scale' simulator, adapted to a specific crane (if desired), and includes correct environments as well as course Curriculum for both operators and instructors.

The Crane Driver Training Package scenarios include most of the common situations found in port operations. Hoisting, controlling sway, and safety checks are some of the basic exercises, [5], [6] and [7]. Discharging and loading containers to and from various types of vessels, and during bad weather conditions, are some of the more difficult exercises.

4. DISCUSSION OF BENEFITS

Automation systems and products contribute to a consistent long term performance. Between any position and target lanes on the quay, or cells on the vessel, an automated travel cycle follows an optimum path saving energy while performing safe and fast travel and accurately positions the load without sway over the target. This is done over and over again regardless of the skill or experience of the crane operator. The consistency and safety in the operation of automated travel cycles come from the fact that the control system executes a safe and predictive behaviour according to set rules regarding path optimisation, obstacle avoidance, safe heights etc. Combined with laser based scanning of the ship and chassis an optimal path in terms of speed, energy consumption and safety is combined with fast and accurate positioning of the load over the target lane or cell enabling faster landings with fewer time consuming mistakes. In fact, the situations where a skilled human operator loses time against automated motion are when mistakes are made; for example during landing on a chassis causing sway or skew motion on the load that the driver has to wait for, or in other ways actively dampen, before landing is possible. Automation does not make these kinds of mistakes thus performing consistently over and over again. On the other hand, this consistency comes at the price of sometimes waiting too long during landing or fine positioning over the target compared to what a human driver might have done before the system is sure of having the correct position without too much motion, in strong winds for example. These are the type of situations where a skilled driver, used to operating with the aid of automation features, can intervene and take over the motion to finish a job when opportunities arise using the superior human sense of timing. The consistent and predictive behaviour of automation make all drivers perform better as they get used to working in close cooperation with the system. This is especially true for those less experienced or skilled, thus making a fleet of STS cranes perform in a more consistent and predictive way that makes berth planning easier since it no longer matters as much who is operating which crane. Driver skill still matters, though, more in the margin of production rates. But since automation can make the driver relax for a longer part of each travel cycle, it thus makes it possible for him to focus solely on the really important sections of a move where it is really possible to save time, such as when landing on the vessel and quay (if this is not done automatically). Thus even a skilled operator will perform better in the long run using his skill and concentration where and when it matters the most. Overall production rates are increased when the difference between skilled and less experienced operators is decreased. If the right incentive strategies are used to encourage all drivers to make full use of available automation features, without making them feel it gets in their way of possibly benefiting from professional skill, it is possible to get more out of every driver and achieve a higher and much more predictive productivity rate. For many terminal operators as well as crane operators and maintenance personnel the concept of automatic systems aiding their work is new and might seem very complex. To the experienced crane operator automation might be looked upon as conflicting with their own professional pride and a source for concern of being marginalised into a supervisor. Other doubts concern the complexity level of a crane equipped with automation systems and products in terms of maintenance costs and the required skill of maintenance personnel and the conception that a more complex object is less reliable. But, since the skill of the operator still affects the performance level of an automated crane as well as for a completely manually operated crane, such doubt can be turned around into the optimism of gaining new tools aiding them in their profession. Perhaps such a change of mindset needs to be accompanied by the proper guidance in terms of a changed view on crane operator reward programmes creating an incentive to encourage this change in opinion towards automation. And as technology improves and products have been around for a longer time, their quality, and reliability increase and the knowledge of their proper maintenance and operation increase. When summarising the feedback from terminal operators having implemented an automated concept, it can be said that initial doubts are often dissolved over time giving way to considerable optimism. However, really taking care to implement operational directives and policies is a key factor in a successful implementation of automation strategies. Success of automation is all very much about the mindset of terminal managers, operators and maintenance personnel. Introducing automation on a small scale can be an opportunity to start the mindset changing process to be ready to keep up with the continuing development in crane productivity to survive in competition. Definitely, automation is changing the container handling

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