

# Overview of user interfaces used in load lifting devices

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**Abstract** — Lifting cranes play a key role in industry. They are used all over the world on construction sites, ships, transport, ports, warehouses and wherever it is necessary to move heavy objects or goods. To control them are hired qualified people who undergo rigorous training. Lifting devices are designed to increase the efficiency of their work and minimize the risk of accidents. But between the operator, and lifting device is an underestimated element. That element determines the performance of lifting equipment and safety in places where they are used. It is a control device - the user interface, which should be the most intuitive, efficient and ergonomic, especially nowadays where time saving is very important.

**Index Terms** — lifting devices, cranes, HMI, control, overview, control devices

## 1 INTRODUCTION

The lifting devices play a key role in industry. They are controlled only by qualified people who undergo rigorous training and used all over the world on construction sites, ships, transport, ports, warehouses and wherever it is necessary to move heavy objects or goods. Lifting devices are designed to increase the efficiency of their work and minimize the risk of accidents. But between the operator, and hoisting device, is one underrated element, which also depends on the performance safety in areas where lifting devices are used. It is a user interface, which should be the most intuitive, efficient and ergonomic, especially nowadays where time saving is very important. In recent years, despite the development of technology construction lifting equipment, control algorithms, or methods of damping of oscillations cargo, little attention was paid to user interfaces and their impact on the operator.

Wooden structures resembling today's lifting devices have been developed in ancient Greece and Rome. The simplest Roman crane trispastos (Fig. 1a) consisted of: one boom, winch, rope and a block containing three pulleys. One man using trispastos could lift 150 kg. It was also constructed its more extended version (pentaspastos), which contained 5 block pulleys. The most advanced state structure was polyspatos (Fig. 1b). It consisted of three sets of blocks, the five pulleys, three lines and two, three or four masts depending on the load. Polyspatos was operated by four men. They could lift 3000 kg using a winch. When the winch was replaced by a mill wheel, the two men could lift 6000 kg. Polyspatos capabilities compared to the structure of the Egyptians (about 50 men were needed to pull 2.5 ton block) were about 60 times greater.

The next stage in the development of lifting equipment began in the Middle Ages when the first harbor cranes were constructed. Harbor cranes were built of wood, and were used for unloading ships and in the shipbuilding yards (eg. putting the masts).

Despite the development of the methods of construction

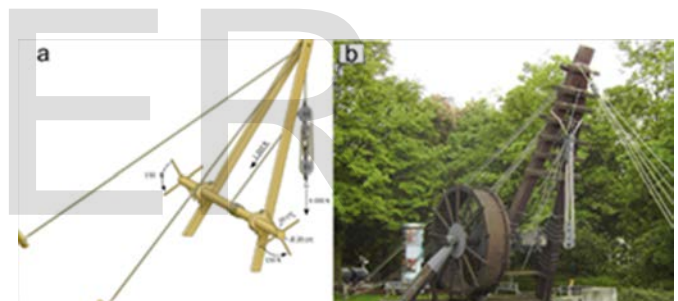


Fig. 1. The first construction lifting equipment

cranes and materials used in their construction, for many centuries the main problem was the driving force. Initially provided mainly by humans and animals, and later also by the forces of nature. It was not until the late eighteenth and early nineteenth century when was introduced the first "mechanical" energy source - the steam engine. It was used for the mid-twentieth century, when it began to come into common use internal combustion engines and electric. Combining them with hydraulic systems made it possible to

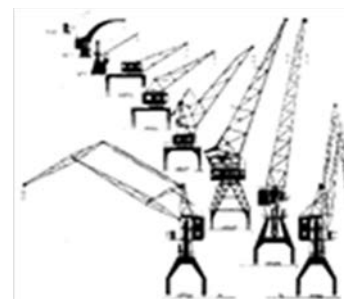


Fig. 2. The development of harbor cranes in the years 1856-1956

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obtain much greater capacity that was previously unattainable. Current modern cranes and gantries constructions are made of steel and steel alloys. Their capacity is several hundred times greater than the structure of previous eras. In addition, lifting devices have become mobile. Driven mainly by electric motors and diesel - coupled with hydraulic systems aided by number of sensors and electronic circuits. However the biggest impact on lifting equipment, has a method of controlling them.

## 2 TYPES OF USER INTERFACES

### 2.1 Description

One of the factors hindering control of cranes is a natural tendency to the load oscillation. Despite the fact that people hired to operate the cranes go through rigorous training and are highly skilled, fast, safe and accurate transfer of charge, without rocking it, is a challenge for them. There is a lot of research on algorithms that have to suppress oscillations and make control easier. However, relatively little attention has been given to the impact on the safety and effectiveness of the user interface. Most manufactured lifting equipment are controlled by a lever directly connected to the hydraulic system (Fig. 3d), wireless or wired cassette control (Fig. 3a), joysticks (Fig. 3b) or control panels (Fig. 3c). These interfaces receive operator's commands, for example: pressing a button. Then send the appropriate signal to the controller where it is converted by a suitable algorithm. The result of this operation is a control signal, which passed to the engine resulting in e.g. trade crane. This chapter will discuss the interfaces used to control a crane, in particular cargo handling cranes.



Fig. 3. Common interfaces in load lifting devices [19-23]

### 2.2 Levers

The mechanisms of lifting equipment, particularly cranes handling the most widely used is the hydrostatic drive. It is responsible for the transfer of energy to the elements by means of fluid under pressure. Therefore, the most basic and oldest control interface, which is part of the hydraulic system are the control levers. Control levers are connected to hydraulic valves (Fig. 4). Valve direct the flow of fluid to the respective hydraulic load by opening or closing flow path. At the

opening part of the flow path followed by reduction of the liquid flow rate. By using valves, it is possible to translate movement of the lever on the corresponding movement of the



Fig. 4. Load sensing valve V91 produced by Olsbergs [20]

crane.

Valves are composed of several sections segments (Fig. 4), each of them is used to control another receiver. Moving the lever by the operator sets the correct position of the slider in the valve. This slider can be set in three different positions (Fig.5). In neutral, the liquid flows directly to the tank, the pressure required to press the fluid is very low, because it results only from the flow resistance. When the slide switch to position one or two - fluid is directed to a respective receiver one channel, and then returns the second valve channel, which results in a corresponding movement of the crane. On release of the operating lever, under the influence of the spring, the slider distributor returns to the neutral position. More comprehensive distributors are equipped with a safety valve and non-return valves. At the time of exceeding the nominal pressure in the pipes conveying pump valve opens and the liquid is directed to a special container. The maximum pressure to which distributors are used is about 350 bar. Their disadvantages include an increase in the force required to move the lever after extended periods of rest. Their

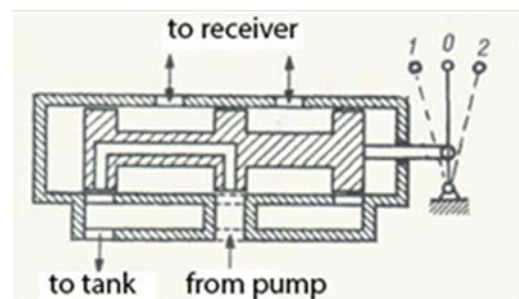


Fig. 5. Diagram of a three-position four-way valve slide [3]

disadvantage is to increase the force required to move the lever after a long idle time.

The user interfaces that use levers, using two layouts: horizontal layout (Fig. 6b) and vertical layout (Fig. 6a). Because the levers are used mainly for controlling the crane from the working level, the standard recommends that they were on both sides of the crane. This procedure allows the operator to directly observe the load while controlling the boom of a crane, regardless of the side from which the cargo was initially set. If the crane is placed on a platform car and levers are only on one side, the control is difficult. The operator, whose job is to precisely set the handled load, have to move away from the steering position and observe the crane boom or need other people help. That actions reduce safety and productivity. Currently, the most commonly used lever system is a horizontal layout, used by Cargotec and Palfinger company. This is due to the fact that the crane (especially with multi-jointed boom) has a lot more possibilities for moving up and down. Horizontal position of the lever is more natural and intuitive for the operator. The vertical position of the lever application is used in cranes manufactured by Fassi.

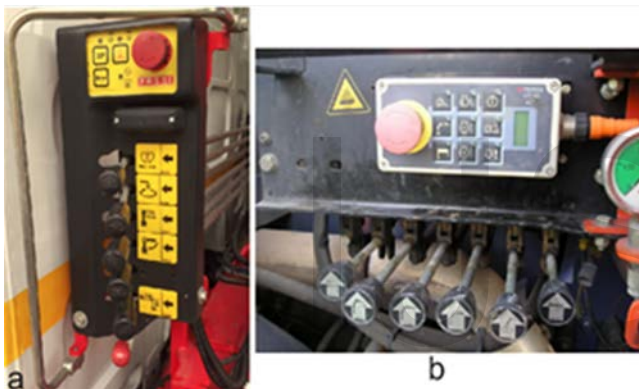


Fig. 6. Control systems for cranes with a vertical and a horizontal lever system [15,17]

### 2.3 Joysticks

Joysticks were originally designed to control the aircraft. In 1909 Frenchman Louis Blériot first applied in their aircraft control stick. It was a piece of pipe removable attached to the floor cabin between the legs of the pilot. Suitable tilting rod resulted in a change in the direction of flight. However, over time these devices have been noticed by the entertainment industry and used as controllers for games.



Fig. 7. Industrial Joystick HFX Series IV  
Source: <http://www.res-rich.com/>

With the development of technology and the increase in structural reliability joysticks also started to appear in the industry. Practically, they replace traditional mechanical levers, which are used in hydraulic systems. Currently joysticks are used in all modern applications where precision is very important to control and intuitive navigation in space. They are applied in lifting and mining equipment, assembly lines and excavators. All mechanical, hydraulic and pneumatic multidirectional levers are also joysticks.

The simplest electrical joystick consists of a shaft rotating on the basis of which the position and the angle are transmitted to the controlled device. It has two or three axes of motion. Joysticks are so constructed that moving the joystick to the left or to the right will generate the movement along the X-axis, while moving it forward (up) or back (down) generate signals along the Y axis. If the device is a three-axle, the signal for the Z axis is generated using additional button (up, down), swivel bar to the left (counter-clockwise) or right (clockwise or counterclockwise) (Fig. 8). There are two types of joysticks - digital and analog. The first type is used in applications where high precision is not required (i.e. Control cameras), because it has limited accuracy, and the speed can be smoothly

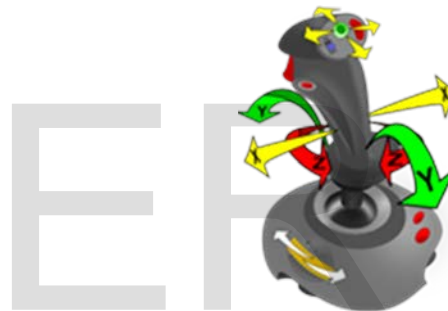


Fig. 8. A three-axis joystick  
Source: <http://www.wikipedia.com>

controlled. In the basic version allows you to specify only a basic four directions and the same intermediate. It is made most often of four contact switches (which activate a circuit only if they are "held" in position "on"). Tilting the joystick in one of eight directions causes the relay contact and generate information about the selected direction. The consequence of this design is that the signal is not dependent on the degree of tilt rod as an analog joystick, a controlled object will not react so smoothly. Digital joysticks are often used in interfaces used to control the towering cranes.

Analog joysticks allow for a smooth indication of pitch, roll and deviations, to the nearest minute of arc. In addition to indicating the direction allow the term "intensity" of its changes by recording the rate of change of the angle of deflection of the rod. Thus, the control becomes more intuitive. For small deflections movements are slower and more accurate and faster for large deflections. Analog Joysticks are often used in the "forest cranes". Joysticks can be divided into three groups:

- Resistive (Fig. 9b) - working by measuring the constant change of the potentiometer. Rotate the potentiometer by swinging the rod along an axis at an angle changes the current value of the resistance, which is converted to the appropriate angle.
- Induction (Fig. 9a) - use non-contact temperature-



compensated Hall sensors to detect the position of the rod. The compensation is necessary to ensure the accuracy in the industrial conditions. In order to obtain the position of the rod at its end magnetized ball is disposed. In its vicinity are located two Hall sensors aligned at an angle of 90 degrees, and the ball is located between them. This design makes the output signal is proportional to changes in the magnetic field caused by the movement of the rod. Furthermore, the dependence of signal from the motion is linear, without hysteresis. Contactless joysticks provide longer reliability, higher resistance to temperature and humidity than potentiometer joysticks. They are most commonly used in interfaces lifting equipment.

- Tensometric (Fig. 9c) - joysticks of this type are small and mostly biaxial. Strain gauges are used to determine the position of the rod. Strain gauges decompose the force applied on the X and Y components, and transform it into a proportional electrical signal. Strain gauges can be mounted directly on the end of the joystick in the sleeve stabilizing or spring, which keeps the rod in the neutral position. To obtain accurate measurement they are often combined in a full or half Wheatstone bridge. The greatest advantage of the strain gauge joysticks is that except the buttons do not employ any mechanical parts and may have small size. This allows to use them in high g-forces, vibrations and strong electromagnetic fields environments. The interfaces lifting devices are used as components of wireless control panels, which are operated using the only finger or thumb (without full hand grip like in



Fig. 9. Types of analog joysticks [15]

a traditional joystick).

## 2.4 Handheld control pedants

Handheld control pedants as well as levers are the primary interface between operator and machine. They allow the issuance of only simple commands and controls using them carried out point by point. Because of the low price, simple design and durability pedants are used in a wide range of applications, such as gantry cranes, tower cranes, electrical machinery, specialized vehicles and many others. Manufacturer offer a lot of different models of pilots, which mostly differ only in the details.

The simplest remote control consists of a rectangular yellow box. It can be equipped with any numbers and types of buttons, emergency stop, various switches, diodes, or ignition. Most pilots have a degree of protection IP65 or higher, making it suitable for use indoors and outdoors. Pedants used in the lifting equipment are equipped with mechanical interlocks

between pairs of buttons to increase security. They prevent pressing two or more buttons in the same time. The pilot control can be connected directly to the motor-controlled machine or control system. The connection to the controlled object can run wire (RS485, CAN) or the more advanced models using infrared or radio waves. For most commonly used radio wave frequency is 400MHz, 900MHz, 2.4GHz.



Fig. 10. Examples of handheld control pedants  
 Source: www.hmbeng.com

A very important part of the handheld pedants are control buttons. They have influence on operator comfort. A smaller number of buttons used interface ensures readability and reduces the size of the cassette, however, limits the functionality of the remote control. The big drawback are two level buttons, which prevents smooth control speeds. The operator, who would like to maneuver a crane in four separate directions, with four speeds in each direction would have to have a pilot with sixteen monostable buttons. Counting for the safety buttons and options, the interface - would consist of about twenty buttons. Such a solution could be awkward not only due to the device size, but also by the amount of available options. The operator can have problems with memorizing function and position of each button. He can make a lot of mistakes.

Therefore, depending on the destination controller

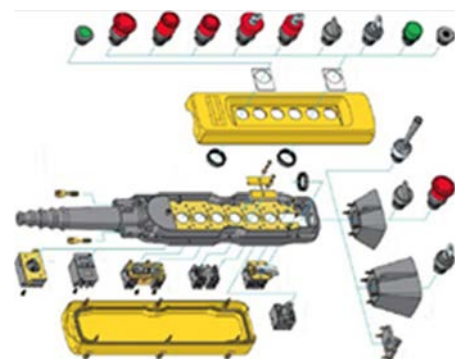


Fig. 11. Construction of XAC's control pedant, Faryuan electric  
 Source: http://www.ele-b2b.com

manufacturers use the buttons with one, two, three or four push levels.

An example could be a pilot produced by the Electromotive, model SBPN-8-WHT which is designed for gantry cranes or lifts, and offers three position buttons. The

use of these buttons controller increases the possibility of providing three levels of speed for each direction, without expanding the cassette. Another solution, extending the possibilities of control by the pilot applied the model micron 5 from HBC (Fig. 12c). It consists in the fact that the remote control buttons are placed just defining the direction of movement and speed, while the mechanism (e.g. base, winch), move selected elements with the switch. The most powerful model pilots are additionally equipped with an LCD screen (Fig. 12b). It shows the currently supported device, the weight load, systemic errors or battery, in the case of wireless remote controller. An interesting feature used in controls pedants

appear about 50 years ago and have been introduced by Liebherr. However, only in recent years, their growth gained momentally, and they become standard for controlling certain types of lifting equipment. Browsing the equipment for loader cranes, forest cranes, spider's cranes, even excavators notice that the wireless control panels are increasingly being offered as standard equipment, not optional. This is so for three reasons. The first reason is decreasing cost of production. Another reason is much greater functionality, safety and efficiency of the operator, who uses them. The third reason is related to increasing reliability and miniaturization of wireless technology. Various wireless solutions are available on the market (radio, Bluetooth, Wi-Fi), but for most users, type of communication between the control and the crane is not critical. Most important are safety and reliability of communication. The pilot should work every time, regardless of weather conditions. The miniaturization of electronic components has allowed the construction of lighter, more ergonomic and easier to use pilots. However, the recent market trend is to increase the amount of information exchanged between the control and the crane and the presentation of their integrated display.



Fig. 12. Construction of HBC radiomatic remote control pedant [19]

HBC is operator identification via an RFID system (Fig. 12a). It is based on the fact that each operator has a personal ID card that is used to activate and identify the user. As you approach the card to the remote operator is identified and then automatically loads his personal settings. This solution protects against unauthorized use and allows you to enter the remote control permission levels depending on the position of the person operating the device.

Loader crane control via the control panel is more efficient and safer. This interface allows the operator to attach a separate cargo hook and transfer it in exactly required position without additional persons signaling. This is because the operator is free to move, along with the desktop, and may at any time send a command to the crane. While hooking the load may approach him, then go to a place where the cargo will be moved. In this way it has always provided an accurate view of the load and the environment, thus minimizes the risk of error or collision. However, during control using the hydraulic levers located on the crane, the load can be blocked by various obstacles, then it is necessary to help another person who will guide the operator.

### 2.5 Remote control panels

Remote fingertips controllers (remote control panel) are more advanced, wireless version of remote controls. Often they are equipped with joysticks, electronic levers, buttons, switches, LEDs and LCDs. Thus allowing for greater control, perform more precise maneuvers, and set many parameters of the crane without entering the cabin or going to the control panel.

The only possible drawback of this solution, relating mainly to larger cranes - is that the crane is left unattended (the operator will leave in place setting load) and is vulnerable to interference passers-by. There is also the opportunity to roll out the crane, which an operator located at the load may be unaware. However, to avoid such situations crane manufacturers have introduced numerous safety systems for example Hiab - VSL (Variable stability limit) or Palfinger - HPSC (High Performance Stability Control). These systems monitor the operation of the crane changing the parameters in this capacity, the operating range and speed depending on changes in pressure on the support legs, the degree eject the supporting beams or changing during the unloading of the actual weight of the truck. In addition, the operator always has the emergency stop button.



Fig. 13. Remote fingertips controllers, HBC, IKUSI, Olsbergs and Sanreco [20,21,22,23]

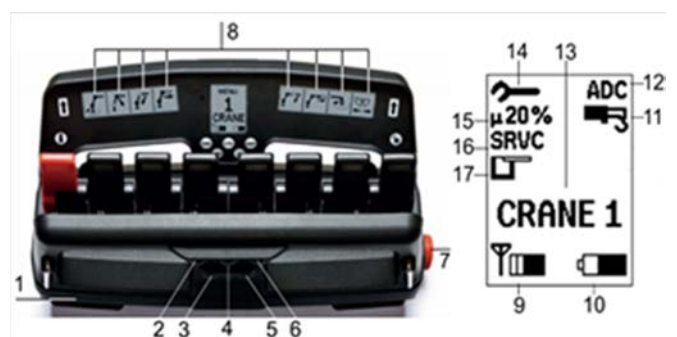


Fig. 14. Wireless control panel CombiDrive2, Olsbergs [15]

On the market of manufacturers of wireless control panels there are many companies, these include: Autec, Hetronic, Teleradio, TECSIS, Ikusi, Imet. However, the most popular controllers are manufactured by HBC radiomatic, Scanreco and Olsbergs. Control panels produced by all these companies are very similar. So now the struggle of manufacturers focused on the size of the device, the presence of the LCD screen, touch panels and the amount of data that desktop can be replaced with a crane. Data exchange with a crane is required for very complex tasks and heavy loads. An operator must receive real-time detailed information about the status of the crane to accurate and safe cargo move. The latest developments are presented on the LCD display. Besides, they can be used as an indication of the function buttons. In traditional systems, the operator must remember the purpose of each button or lever, depending on the mode in which it is located. The pilots are equipped with LCD displays mode of operation and function of each lever is changed and displayed automatically. This section presented the consoles used by most manufacturers of loading cranes: Cargotec, Palfinger and Faasi.

### 3 SUMMARY

In this work lifting equipment and their basic parameters were described. User interfaces are also presented. Principle of operation of each of the controls, the latest models of the cranes and their capabilities, strengths and weaknesses were discussed.

The biggest difficulty was to obtain information about crane. Companies that produce lifting devices keep details about construction, algorithms and parts in secret. In addition, attention was drawn to a solution prototype, which tested at universities and research centers. Overview of current research shows that slowly there are attempts to modernize and improve the structure of traditional controls. Noticeable is the trend to provide more intuitive ways to control lifting devices with using more operator senses. However, introduction this new methods in industry need a lot of time and labor. Each innovative solution hides a lot of problems, such as changing the habits of operators, localization operator's position in relation to the lifting device to ensure compatibility control axis, sending large amounts of data from places where there is no cellular phone coverage (cranes), separating the voice of the operator of sounds from the outside (e.g. voice commands on the site) and many others.

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