Development of Unmanned Caisson Installation System (UCIS)

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Abstract:
Unmanned Caisson Installation System (UCIS) is an unmanned and remote-control technology though wireless LAN for performing a series of operation involved in caisson installation, which has been performed on caissons by manpower. The system enables one operator in a remote control room to perform diverse works involved in caisson installation, such as pouring water into the caisson and manipulating winches, and thus sharply reduces the required manpower. The system also ensures the safety of caisson installation works since there will be no persons on the caissons. It also improves the efficiency and precision of the works since the IT-based system centralizedly controls the movement of caissons and pouring and discharge of water. This paper describes the performances of the system and an example of actual application of the system.

Keywords: UCS(Unmanned Construction System), Caisson Installation, Wireless LAN

1. Introduction

Breakwater construction in harbors involves installing caissons, which has been performed by floating a large caisson, manipulating several haul winches by approximately 10 workers boarded on the caisson to move the caisson to a predetermined location, and injecting water using several pumps by monitoring the water levels in the chambers. Since the surface of a caisson is congested with wires for moving the caisson, water and drainage pumps, and other devices, the space over the caisson is not only difficult to work but is also dangerous since wires may strike the workers on the caisson when they break due to extensive tension caused by waves, etc. Moreover, caissons must be maintained leveled throughout the installation work, and the conventional method requires workers to operate water and drainage pumps by monitoring the water level in the chambers and is inaccurate and inefficient.

Thus, a new one-man-operated remote-control system for installing caisson was developed by extracting factors involved in the work. The background of the UCIS development is shown in Figure 1.

Today, unmanned construction systems for land works have already been deployed. Most of these systems are based on remote control by monitoring images from cameras. However, information from camera images is insufficient for remote installation of caissons since the marine environment, in which caissons are to be installed, is never constant. Just providing environmental data, such as winds and waves, to the operator is likely to not solve the problem. Creating a virtual reality space around the operator of being on the caisson is not practical. Thus, two modules were added to the UCIS: a module for assisting appropriate human operation and a module for supplementing human operation. In the former, the system provides the operator, who remotely controls winches and pumps, with guiding information of remote monitoring items other than camera images, as well as camera images, based on the goals and rules determined in advance. The latter, or the module for supplementing human operation, is a fail-safe multiple safety circuit system for predicting and avoiding danger to enable works to be performed in constantly changing oversea environment.

Figure 1 Background of UCIS development

2. Overview of the system

(1) Overview

The UCIS is a remote control system to improve the efficiency and safety of works by centralizedly monitoring and controlling caisson movement, winches, and water and drainage pumps via wireless LAN. A schematic diagram is shown in Figure 2, and a flow of caisson installation is shown in Figure 3.

(2) Characteristics

The system has the following characteristics:

1) It remotely and centralizedly monitors caissons (position, direction, and inclination) and the water levels in the chambers and operates haul winches and water and drainage pumps.
2) It is installed with a fail safe system that enables safe and certain installation of caissons.
3) It can monitor and operate from a distance of up to 500 m.
4) The system enables one operator to monitor and install caissons.

3. System configuration

The UCIS consists of four key technologies, which are shown in Figure 4.

1) Remote system for monitoring the movement of caissons, the water levels in the chambers and the operation states of winches and water and drainage pumps,
2) Remote system for operating winches and water and drainage pumps,
3) Multiple safety system consisting of multi-channel systems for transmitting emergency stop and for operating winches,

and

4) Devices for predicting and avoiding danger, such as torque limiters of winches and alarm equipment warning abnormal system operation.

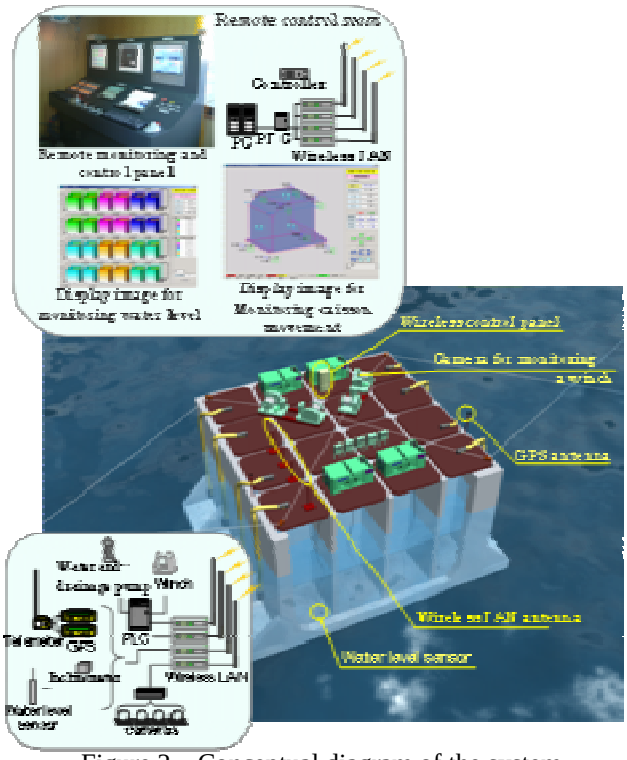

Figure 2 Conceptual diagram of the system

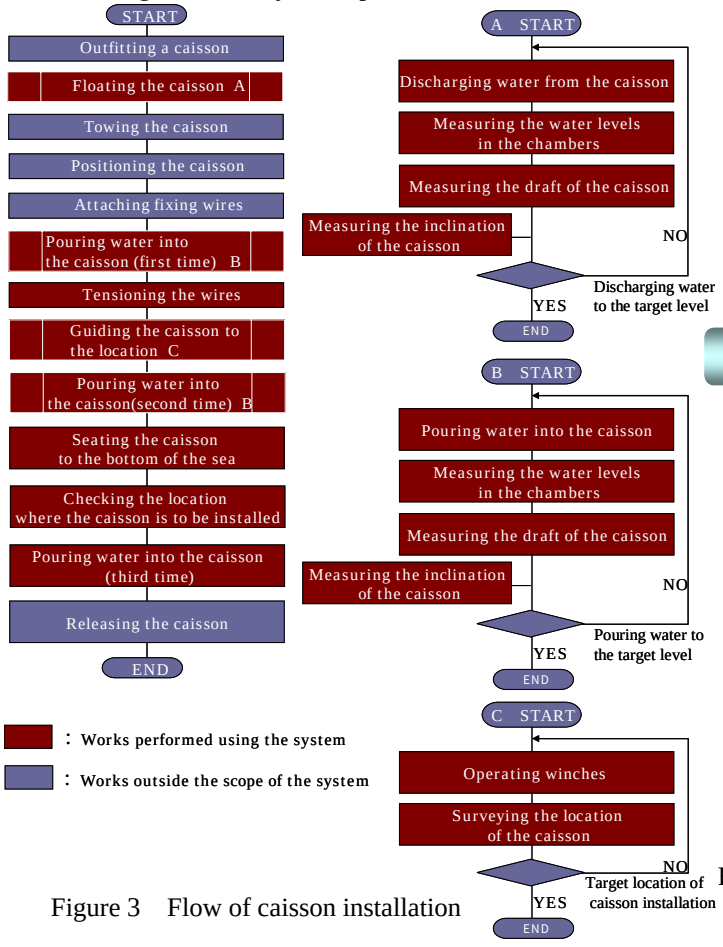

Figure 3 Flow of caisson installation

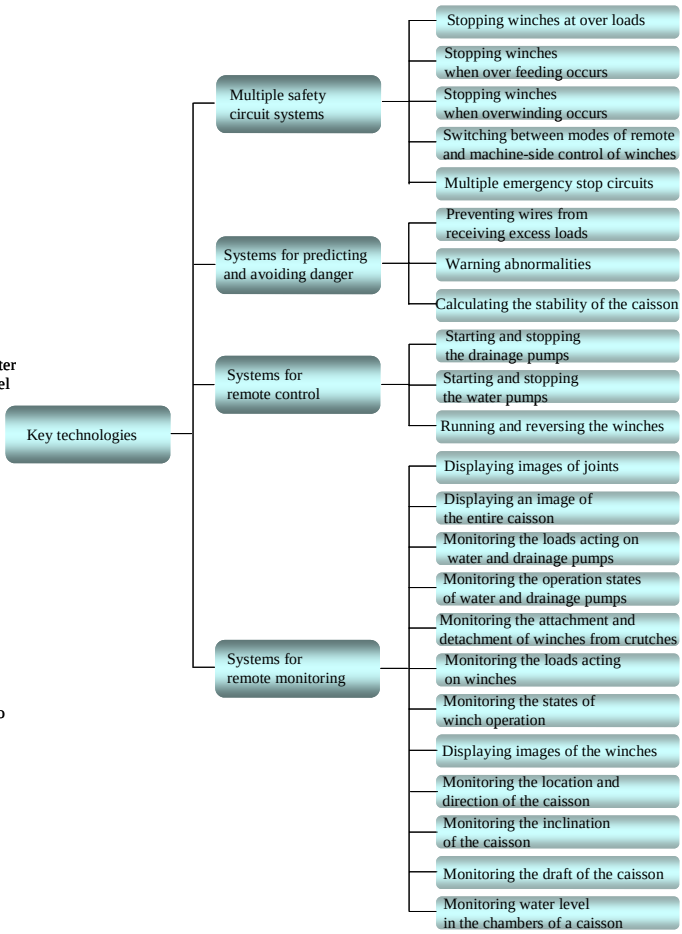

Figure4 Key technologies of the Unmanned Caisson Installation System

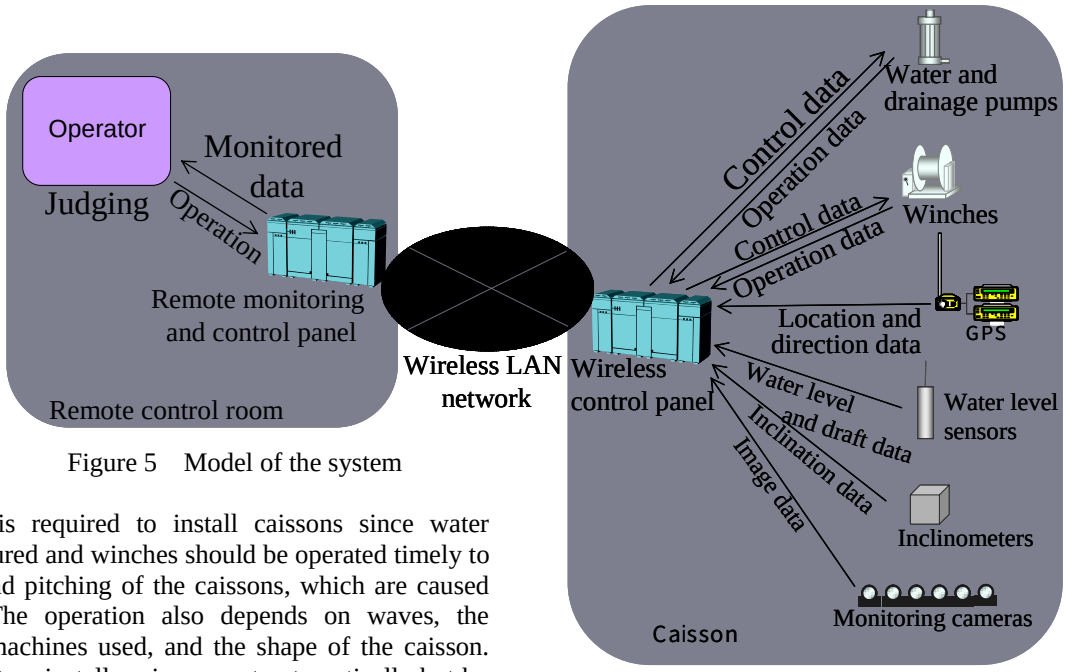

Figure 5 Model of the system

Expertise is required to install caissons since water should be poured and winches should be operated timely to the rolling and pitching of the caissons, which are caused by waves. The operation also depends on waves, the capacity of machines used, and the shape of the caisson. Thus, the system installs caissons not automatically but by an operator from a remote place. A model of the system is shown in Figure 5. An operator makes judgments and operates machines based on information from instruments installed on the caisson.

Instruments on the caisson include an RTK-GPS receiver for determining the location and direction of the caisson, inclinometer for measuring the inclination of the caisson, water level gauges for monitoring the water levels in the chambers, a draft gauge for monitoring the draft, hauling winches, water and drainage pumps, monitoring cameras, and a wireless control panel. In the remote control room, a remote monitoring and control panel is installed to monitor and control the instruments on the caisson.

Throughout the entire process of caisson installation, sensor data, images and control signals are communicated between the wireless control panel and the remote monitoring and control panel through wireless LAN. The operator watches the monitor on which the information is displayed to correctly understand the movement of the caisson and the water levels of the chambers and can alone operate two or more winches and several tens of water and drainage pumps efficiently from a remote place. A remote monitoring control panel is shown in Figure 6, and a wireless control panel is shown in Figure 7.

Figure 6 Remote monitoring and control panel

Figure 7 Wireless control panel

4. Fail safe technologies

The introduction of the UCIS will improve the safety of caisson installation works since there will be no workers on the caissons, but unmanned operation may also face other kinds of risk.

Risk factors include:

1) Maintaining the stability of caissons,
2) Bad wireless LAN communication,
3) Sudden over feeding and over winding of broken wires, and
4) Duplication of remote operation and machine operation.

To avoid these problems, the aforementioned multiple safety systems and systems for predicting and avoiding danger are implemented. These mechanisms are indispensable since unexpected effects by external factors on caissons and malfunctioning of systems may lead to

serious accidents in unmanned installation of offshore caissons.

Water level measurements in each chamber and inclinometer data may be insufficient for remotely controlling draining water from caissons in which the center of gravity of the caisson shifts from the center of buoyancy when the same amount of water is poured into and discharged from all chambers, such as those for the upper slopes of banks. Thus, the UCIS calculates the appropriate water levels in the cambers in advance, sets the simulation results as the ultimate and intermediate target water levels, and displays the then target water levels on the monitor to control pouring and discharge of water while maintaining the stability of the caisson.

Winches are to be remotely controlled by continuously transmitting winch operation signals when the control lever is inclined, and no self-maintaining circuit is used. This is to prevent unintentional movement of the winch when the wireless LAN fails to transmit signals. Multiple emergency stop circuits are ensured, and the system can be shut down during emergencies even when one wireless LAN circuit links down.

To prevent damages by breakage of winch wires, the system is equipped with a mechanism for detecting over winding and over feeding of the wires and stopping the winches. However, the wires are very little likely to break since each winch is equipped with a torque limiter, which automatically release the wire when a load exceeding and arbitrarily set load acts on the wire.

Like all other remote control systems, the switch for changing the control modes from remote to machine-side and vice versa is on the machine to prevent duplicate operation. The system also enables the loads acting on winches and water and drainage pumps to be monitored from a remote place and warns when the machines receive excess loads.

5. Example of system application

The UCIS was used to install two caissons (weight: 8,900 tons, 30 m (D) × 26 m (W) × 22 m (H)) of a breakwater for controlling damages to onboard cargos by swells (long-period waves), which are characteristic to the Pacific coast. The construction of the foundation on which the caissons were to be built started in 2000, and this caisson installation project was for the installation of the first caissons of the breakwater.

The first caisson was installed on December 6, and the second caisson was installed on December 16. The caissons were floated and towed to the specified sites approximately 2 km off the shore. An operator in a remote control room about 300 m from the sites operated and monitored the work centralizedly. On both days, the meteorological pressure pattern was that of the winter type, and adverse effects by high waves were concerned for. The use of the UCIS enabled safe and smooth installation to be performed.

Views of the caisson installation are shown in Figures 8 and 9.

Figure 8 Installing caissons

Figure 9 Remote monitoring and controlling installation work

6. Conclusion

Efficient and cost-reducing construction technologies are increasingly demanded accompanying changes in the environment surrounding the construction industry. Safe construction systems are needed to cope with reductions in experts and aging workers. The author expects this unmanned installation system be an aid to solve these problems.

Finally, the author would like to sincerely thank all people involved in the development and implementation of the system.