

Development of Luffing Jib Crawler Crane CCH3000LJ

TERAUCHI Tetsuyuki : Design Engineering Department, IHI Construction Machinery Limited

KAWAMOTO Ryo : Assembling Group Yokohama Works, IHI Construction Machinery Limited

NAKAJIMA Takashi : Quality Control Group Yokohama Works, IHI Construction Machinery Limited

MIMURA Hitosi : Formerly of the Design Engineering Department, IHI Construction Machinery Limited

MACHIDA Masakazu : Design Engineering Department, IHI Construction Machinery Limited

In recent years, the need for the construction of social infrastructure, particularly in developing nations such as India and Southeast Asia countries, has greatly increased. In these circumstances, IHI Group is making contributions to development in such countries through the construction of infrastructure such as thermal and nuclear power plants, bridges, and flood gates. As leading players in such massive construction projects, the crawler cranes provided by IHI Construction Machinery Limited are having increasing opportunities to shine, and through the realization of even larger-scale modular construction methods, we are contributing to increasing our customers' level of construction efficiency. Furthermore, we compete with other manufacturers through our efforts to introduce new models of large construction equipment and to increase our equipment's fundamental capabilities, such as lifting capacity. Now, IHI Construction Machinery Limited has developed a crawler crane that not only can compete in head-to-head contests with its rivals with regard to such fundamental capabilities, it can also contribute to the making of total cost savings by our customers, as it also includes a number of added-value features. For example, it can be assembled in a short period of time and moving it requires only a limited number of transporters.

1. Introduction

A crane is a machine that uses the power of a motor to lift and convey loads. Among various types of cranes, those with engines enabling them to freely move around are called mobile cranes. IHI Construction Machinery Limited (IHI CM) has long offered crawler cranes, which are mobile cranes equipped with band-like treads called crawlers as seen on tanks and bulldozers (Figs. 1 and 2).

The hitherto core products of IHI CM include ① cranes having one arm called a boom, and ② tower cranes with a second arm called a jib at the tip of the boom and a jib hoisting unit which made it possible to perform work with greater flexibility.

Meanwhile, IHI CM is pursuing development of a



Fig. 1 Luffing jib crawler crane CCH3000LJ (Longest configuration)

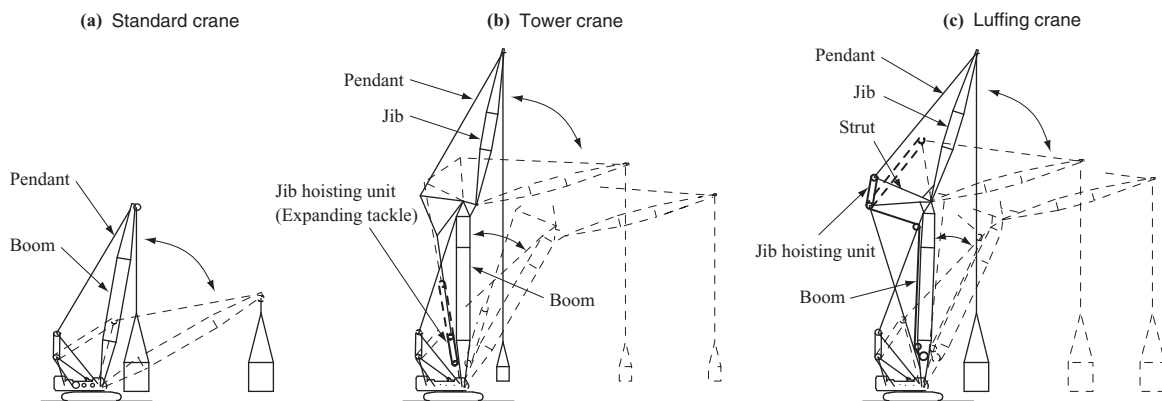


Fig. 2 Types of crawler cranes

product line-up of luffing cranes. A luffing crane is a type of crawler crane whose main boom and luffing jib boom exhibit great flexibility in maneuvering similar to tower cranes. While the jib hoisting unit is deployed close to the main body in the case of tower cranes, the unit is deployed immediately next to the jib in the case of luffing cranes. For this reason, luffing cranes can more directly hoist the jib. The extensive use of luffing cranes is attributed to the advantage they offer in being more conducive to increasing lifting capacities.

2. Development of luffing cranes

Crawler cranes have recently been shifting their area of appeal to infrastructure development and plant construction, primarily in emerging economies. In these job sites, flexible loading performance is required for lifting and placing a large component hung from under the jib and for conveying a component into a building. Moreover, the recent trend of large, modularized loads intended to reduce construction periods urges an increase in the hoisting capacity of cranes.

In line with this trend, IHI CM has developed a luffing crane, the CCH3000LJ that provides both high lifting capacity and maneuvering flexibility based on the crawler crane CCH3000, IHI CM's largest existing model in the market with a lifting capacity of 3 000 kN. The overview is as follows.

3. Achieving superior lifting capacity

In the development of the luffing crane, a greater increase in the lifting capacity was pursued along with the technical development necessary for a larger crane.

3.1 Development of steel plate pendants

The pendant is a thick rope (cable) supporting the boom. Conventional pendants are mainly made of wire rope. As cranes grow in size, the wire rope also grows in diameter. However, the fabrication limit is increasingly evident, a fact urging us to find an alternative technology such as replacing the wire with other steel materials such as steel plates or tubes.

Steel plate pendants demonstrate numerous benefits, such as easier handling during assembly and transportation compared to conventional wire, as each unit of the single pendant maintains its shape even after disassembly. For this reason, many companies including Chinese and overseas manufacturers, are increasingly adopting steel plate pendants.

On the other hand, the track record of their application is insufficient compared to wire rope pendants. Trouble with this key element can immediately result in major accidents. The key challenge, therefore, is how to ensure reliability in the long-term.

This crane adopted a simple design using a link made of high tensile steel plate cut into the needed shape, considering the reliability of the fatigue strength. Verification of the performance was made possible with the actual design, size, and load by employing the fatigue

testing machine owned by IHI, which boasts one of the largest load capacities in Japan. As a result, the test verified that the fatigue strength of the steel plate was sufficient as it can endure a repeated load for decades (Fig. 3).

Other causes for concern such as wind-induced vibration, aside from strength, were also identified and addressed by test validation thanks to cooperation from IHI.

3.2 Structural rationalization

The lifting capacity of crawler cranes is almost entirely dependent on their ability to withstand the force that would tip them over as they lift up a load. This "ability" comes from the counterweight and related specifications such as the span and length of the crawlers. Given such physical constraints, companies are making slow but sure progress in the competition to devise improvements such as reducing the weight of the boom structure.

In developing the new crane, IHI CM incorporated its own original structure mainly to the jib hoisting section for rationalizing the structure. It went one step further by making full use of the Finite Element Method (FEM) to verify buckling, fatigue strengths, and so forth. The strut structure is shown as an example (Fig. 4).

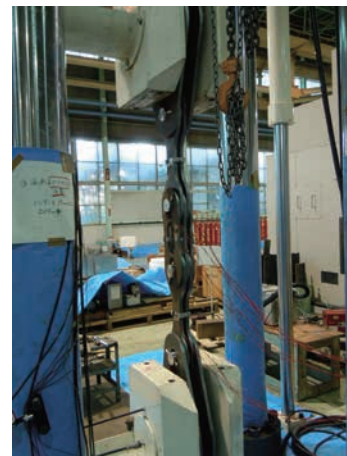


Fig. 3 Strength test of pendant using 2 000 kN fatigue testing machine

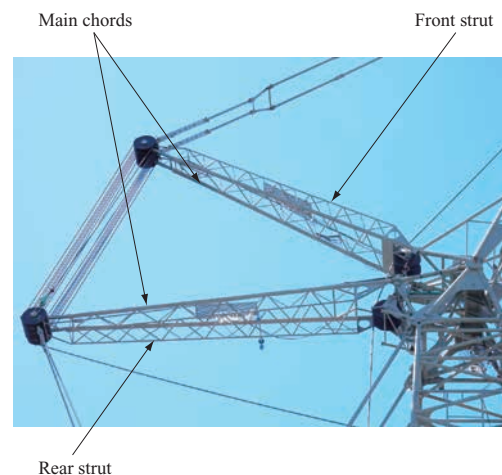


Fig. 4 Appearance of strut structure

The new crane adopted a lattice structure for the jib hoisting section called a “strut.” The lattice structure consists of four chords carrying the load and braces that connect the chords in a truss-like structure. This is known as a rational structure that is lightweight yet strong at the same time.

Previously, however, the center line of each chord was displaced from the axis of the load connecting both ends and the load points of the strut. Accordingly, the force had to be shifted from the chords to the load axis in a meandering manner, which required bending or welding of chords at an angle. This inevitably made the structure complicated and added weight.

We overcame this problem by adopting a rationalized lattice structure with four chords having different strengths. The two main chords with sufficient cross-sectional area to support the entire load were attached in almost perfect alignment with the load axis to provide a simple lightweight structure without causing the force to meander.

The remaining two chords were attached away from the load axis so that they only provided support to prevent the buckling of the entire strut. The cross-sectional area was kept to a minimum to achieve light weight (Fig. 5).

The tackle that constitutes part of the jib hoisting section can pull but cannot push the jib. Operation is impossible unless the jib is leaning forward even when it is raised up high. In order to balance the weight in the front and back of the jib, weight needs to be added to the jib in order to obtain a forward leaning posture when the heavy weight of the struts otherwise causes the jib to lean backward. For this reason, making a light weight strut opened the way toward further weight reduction on the side of jib.

The abovementioned effort achieved superior lifting capacity almost equivalent to the next higher class while maintaining specifications of the undercarriage including the counterweight (Figs. 6 and 7). In terms of expansion of

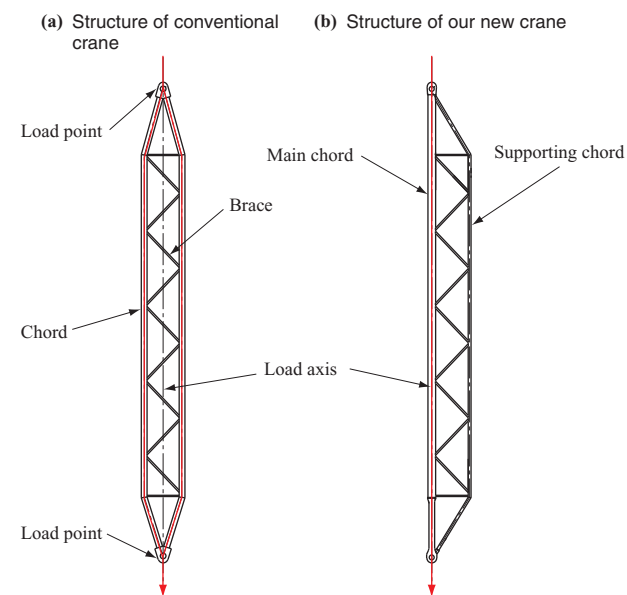
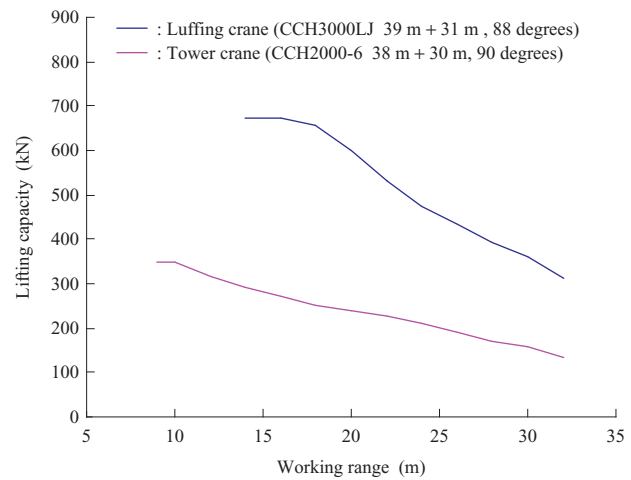


Fig. 5 Comparison with conventional strut structure (side view)



(Note) Comparison with the tower crane by IHI CM having the greatest capacity

Fig. 6 Lifting capacity

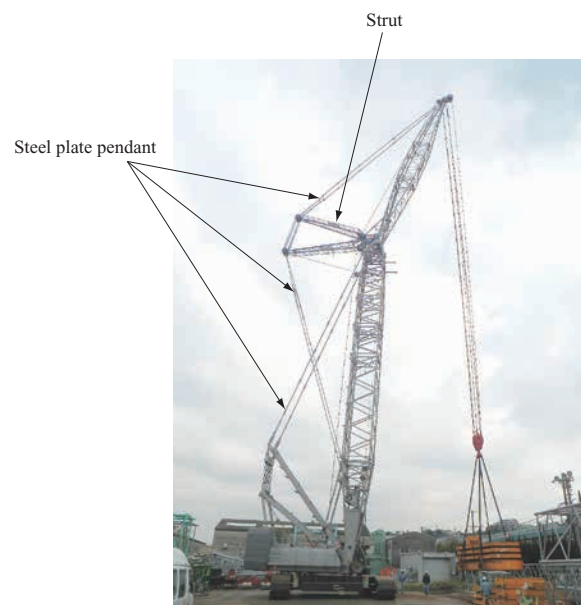


Fig. 7 Overload test

the working range, the new crane offers operation with a boom length up to 66 m and jib length up to 67 m. It thus has achieved one of the longest reaches and load-lifting heights among other 2 500 to 4 500 kN-class luffing cranes with standard configuration in Japan (see Fig. 1).

4. Substantial reduction of assembly time

Aside from the need to increase lifting capacity, great expectation is placed on the compression of the currently large share of costs associated with transport, assembly, and disassembly that make up a large share of the total running cost of crawler cranes. In this respect, the jib hoisting unit that characterizes luffing cranes has a complicated structure including a tackle unit that joins together the two struts, sheaves on their tips, and hoisting rope. The crucial challenge is how to reduce the time necessary for each process of ① transportation, ② assembly, and ③ erection of the boom to

the operational position. The economic efficiency is another issue of concern, which involves, for instance, the necessary number and lifting capacity of so-called service cranes, or auxiliary cranes used for the sake of assembling the desired crane. In response, a solution such as equipping it with a self-assembling unit is necessary (Fig. 8).

4.1 Superior mobility — making the jib hoisting mechanism into a unit —

In the new crane, in addition to the simplification and downsizing of the strut with application of the original structure, the segment including the jib hoisting mechanism and the jib base called the inner jib was successfully made into a unit by optimally aligning each component. The downsizing was achieved so that the unit can be loaded on a low-floor 10-ton truck to save transportation costs (Fig. 9).

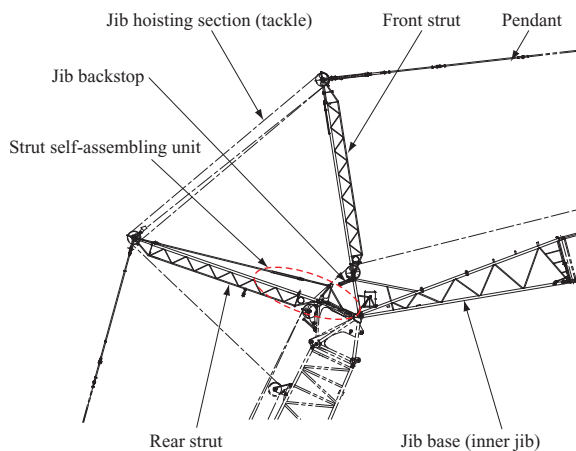


Fig. 8 Jib hoist unit with luffing jib specification

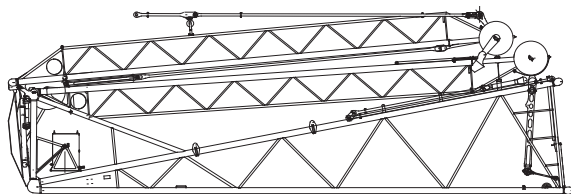


Fig. 9 Jib hoist unit

(a) Transportation to the job site



(b) Connection to the tip of the boom

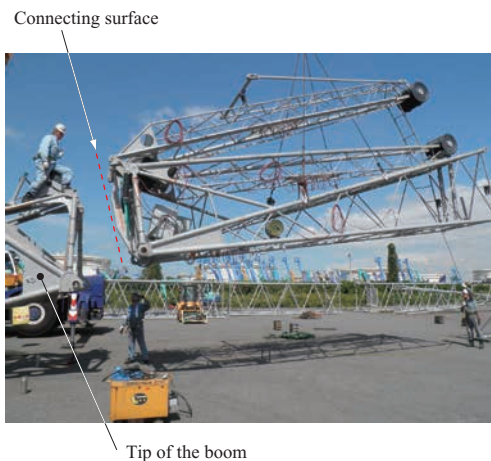


Fig. 10 From transportation to connection of jib hoist unit

The unitization could substantially compress the assembly time as the unit can be transported to the job site when the assembly is almost completed and connection with the tip of the boom can be completed on only one side (Fig. 10).

4.2 Easy assembly — development of a self-assembling unit —

A self-assembling unit was developed for the jib hoisting section of the new crane, which achieved labor-saving for a series of assembly-related tasks for the hoisting section as follows (Figs. 11 and 12):

- (1) Shifting to the wiring position by raising the strut
- (2) Connection of a pendant by leaning the strut backward
- (3) Tightening the pendant by erecting the strut

Driving the strut involves reversal of its center of gravity back and forth. This is why the conventional driving method using service cranes to lift it up is dangerous. This newly developed unit maintains a grip on the strut even during the reversal of the center of gravity. And the unit can be driven and controlled for stable and safe operation.

Adoption of this unit can halve the number of workers needed to set up the crane, since only two persons, namely one crane operator and one operator of this unit, are necessary for performing the operation to feed the hoisting rope. The redundant workers or service cranes may be concurrently employed for other tasks for assembling the jib.

In addition, this self-assembling unit has the following features:

- (1) The self-assembling unit is mounted on the desired unit to be assembled. It can be started up just by connecting to a power source such as a portable generator.
- (2) Simple operation consisting only of the expansion and contraction of the cylinder using the attached remote controller and insertion and removal of a pin in one spot. Even during crane operation after assembly, this unit prevents the drooping of the strut due to its own weight.

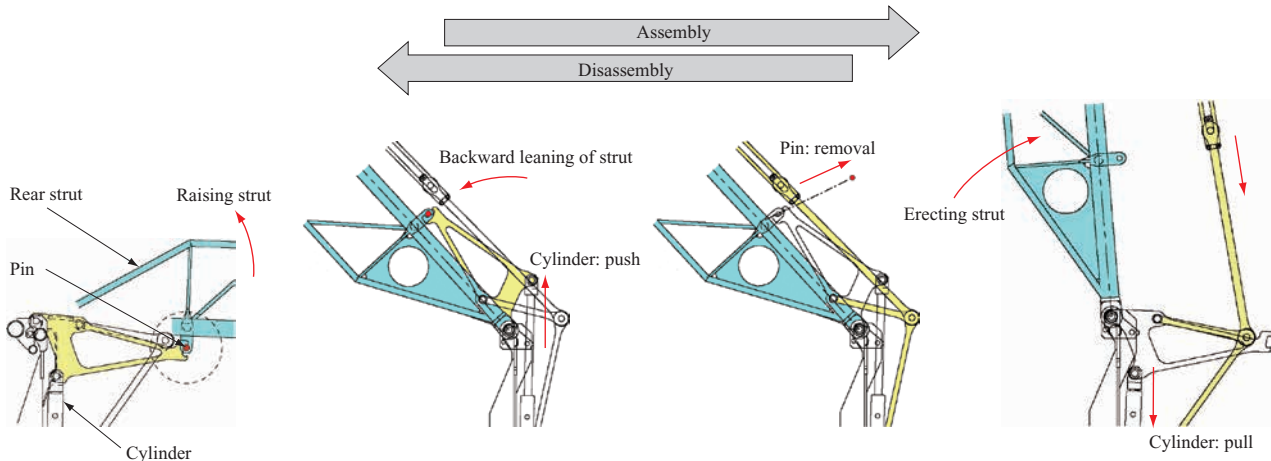


Fig. 11 Operation of self-assembly equipment for jib hoist unit

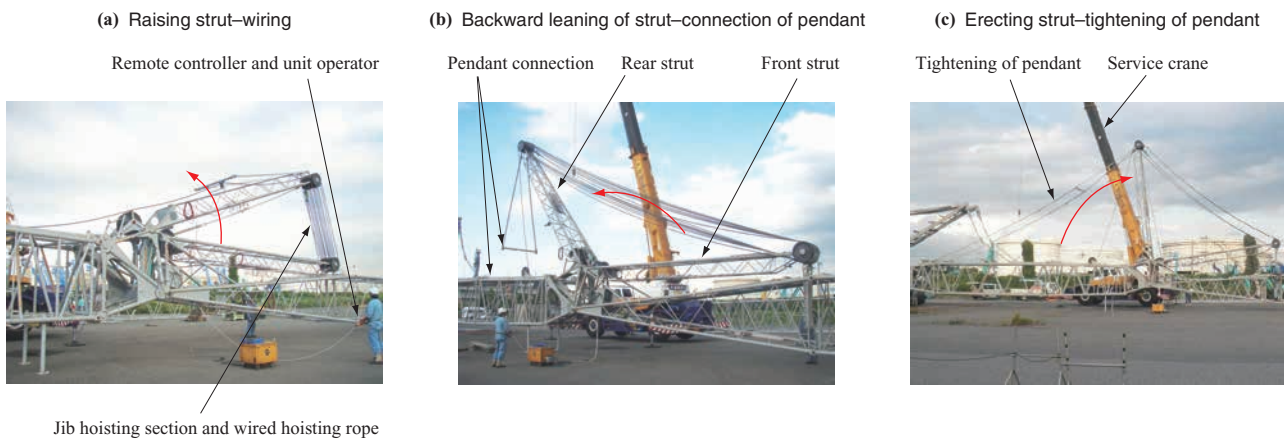


Fig. 12 Assembling of luffing jib specification

4.3 Smooth erection — development of driven mechanism —

Many components of a luffing crane such as the strut and pendant are either not installed or remain folded when erection is started. Erection must take place simultaneously with the raising of the boom while installing or expanding them. Moreover the task must be performed at a high altitude without any troubles.

Mechanisms for performing this task smoothly are built in many spots of this new crane. One example is the driven mechanism for installing the jib backstop (Fig. 13).

The jib must always be leaning forward against the boom while the crane is in operation. The jib backstop blocks the backward leaning of the jib that exceeds the allowable limit. Normally, laying the boom and jib of a luffing crane on the ground involves putting them almost in a straight line. So it is necessary to remove the backstop beforehand and reinstall it once erection is started.

The developed driven mechanism uses a cam that enables erection of the jib backstop, the movement of which is interlocked to and driven by the erection movement of the front strut. The cam curve was optimized so that the front strut and the backstop erect at the most desired angle and timing.

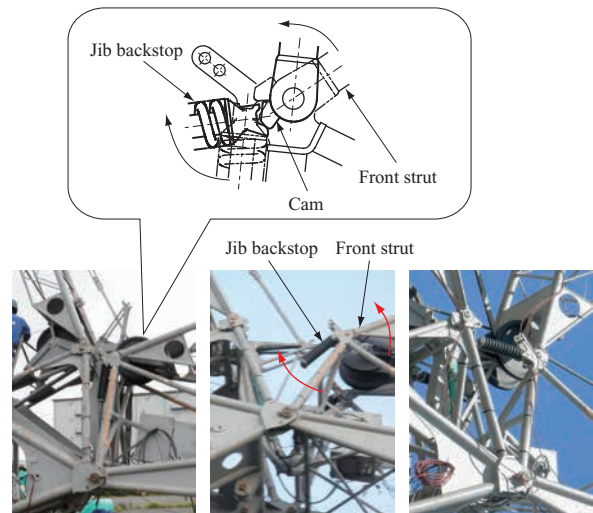


Fig. 13 Jib backstop and following mechanism

Simplification and labor-saving of erection were thoroughly pursued for this new crane. One example is the automatic storage of the pendant (Fig. 14).

This new crane is equipped with a container for storing the pendant on the upper surface, for example, of the jib. When the jib is brought down, the pendant automatically

(a) A view of erection, automatic feeding and storage of the pendant

(b) Erection completed



Driven mechanism for installing jib backstop

(Note) : A view of automatic feeding and storage of the pendant

Fig. 14 Boom erection of luffing jib specification

falls into and is stored in this container, which can be transported directly. When the jib is hoisted, the pendant is automatically fed by the erection movement of the strut.

It depends on the configuration, such as the length of jib, of each individual crane, but erection involving the following two steps was achieved most configurations:

- (1) Erection of the boom to the designated angle followed by extension of the pendant
- (2) Continuing erection of the boom to the working range to reach the working posture

4.4 Clear procedural guidance — development of an instruction monitor —

Cockpits of cranes are equipped with the controlling device integrated with a monitoring screen called a load moment indicator. During crane operation, the device displays the lifted load and monitors its overturning moment. Striving to offer even more user friendly devices for the new crane, the assembly/disassembly modes were developed and installed to guide operators through the procedures related with erection on the display (**Fig. 15**).

This mode displays what needs to be done next, for instance, lever operation for hoisting the boom, as well as the target angle in a self-explanatory manner for the operator. In addition, precautionary instructions for each stage of erection are also displayed along with an alarm

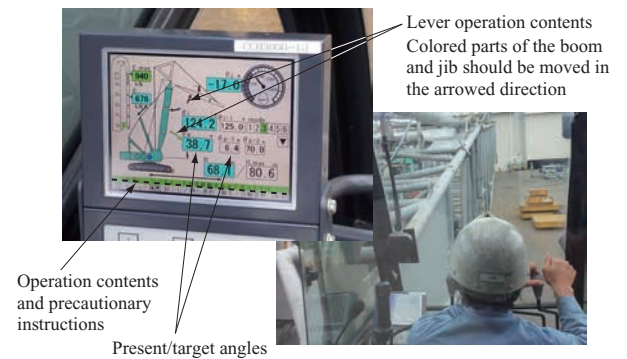


Fig. 15 Instruction monitor for boom erection

sound to catch the operator's attention. Thanks to these instructions, the operator can safely perform erection operations without hesitation.

5. Future development

We will continue to develop user-friendly cranes while delivering the newly developed CCH3000LJ to the market. In addition, the newly developed luffing mechanisms and steel plate pendant will be deployed for other models with the aim of enriching our product line-ups and to enhance their performance.