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Short-Term Renewal Technology Using "All Block Construction Method"

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Abstract:

In large-scale construction work at steelworks, it is required to radically shorten the construction period so as to minimize the production impediment. The conventional technology, "Large block construction method" which the equipment is manufactured with about 5 division blocks and installed, was established as representative of blast furnace refurbishment. However, its machine installation accuracy was within ±10 mm and was limited to the level of boiler manufacturing. JFE Steel has developed "All Block (Integrated Machine Equipment) Construction Method", and has expanded its application to installation work of precision machinery equipment which requires mounting accuracy of machines within ±0.1 mm. It greatly shortened the renewal term.

1. Introduction

In large-scale construction at steel works of JFE Steel, a radical shortening of the construction period is required so as to minimize the impact on production. As a conventional technology, JFE Steel established the "Large block construction method" as a representative technology for blast furnace refurbishment. In this method, the equipment is manufactured in advance and installed in about five blocks. However, its machine installation accuracy is within ±10 mm and thus had been limited to the level of boiler manufacturing. In recent years, application to installation of precision machinery equipment, which requires machine installation accuracy of ±0.1 mm, has been demanded. This paper introduces the development of the JFE Steel original technology, "All Block (Integrated Machine Equipment) Construction Method," which is a further development of the conventional "Large block construction method," together with examples in which the world's shortest construction period was achieved by applying the developed method to various types of construction in the steel works.

2. Conventional Short-Term Renewal Technology

2.1 "Large Block Ring Construction Method" for Blast Furnace Refurbishment[1)]

A blast furnace is a large-scale structure with a height of 110 m above ground level and a gross weight of approximately 10 000 t. In blast furnace refurbishment work, the existing furnace body is dismantled and a new body is assembled. Conventional blast furnace refurbishment was labor-intensive work in which dismantling and assembly were performed by dividing the furnace body into 500 to 1 000 blocks with a unit weight of several 10s of tons. The "Large block ring construction method" was a revolutionary construction method in which the new furnace body was divided into 3 or 4 blocks that were manufactured in advance as large blocks weighing about 2 000 t each, and site work during the renewal work was limited to transportation and joining of the blocks. **Figure 1** shows the conventional renewal method, and **Fig. 2** shows the large block ring method.

Although conventional blast furnace renewal required around 130 days, JFE Steel dramatically shortened the renewal period by applying the large block ring construction method, beginning with the relining of No. 6 blast furnace at East Japan Works (Chiba) in 1998. The results of recent blast furnace renewals at JFE Steel are shown in **Table 1**.

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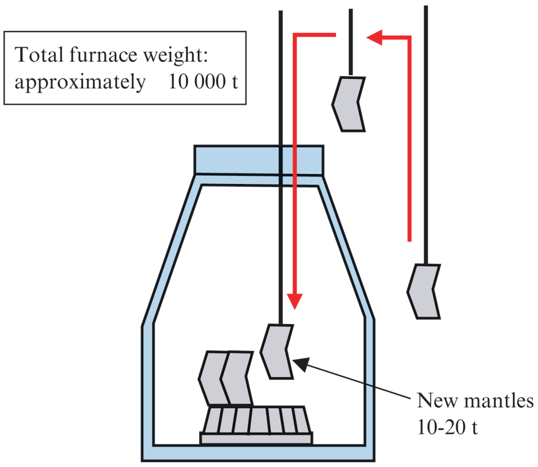

Fig. 1 Conventional renewal method

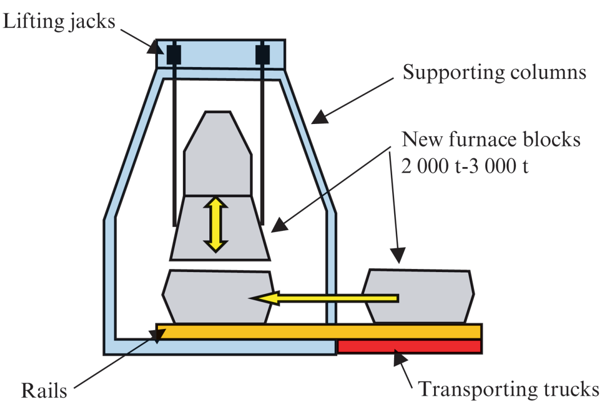

Fig. 2 Large block ring construction method

Table 1 Renewal duration by large block ring method

	Chiba No.6 BF	Kurashiki No.4 BF	Kurashiki No.2 BF	Fukuyama No.5 BF
Renewal duration (day)	62	70	75	58
Renewal time (year)	1998	2001	2003	2005
Inner volume (m^3)	5 153	5 005	4 100	5 500

2.2 Results of Large Block Construction Method

JFE Steel applied the large block construction method to welded structures at its respective steel works, beginning with blast furnace refurbishment and also including renewal of pickling line tanks in the cold rolling process and other equipment. As a result, the renewal period when using the conventional construction method was shortened by approximately 30 to 50 %, and the impact on production was minimized.

This large block construction method also has safety-related advantages. With the conventional method, a large number of personnel were deployed in high places and worksites with limited areas, and the dismantling and assembly works were carried out sequentially. However, with the large block construction method, site work was reduced to about half of the conventional amount, and the risk associated with that work was greatly reduced.

3. Development of All Block Construction Method

3.1 Problems of Large Block Construction Method

Although JFE Steel achieved certain results by applying the large block construction method to new construction and renewal of welded structures, its machine installation accuracy was only within ±10 mm and thus was limited to the level of boiler manufacturing.

At the steel works of JFE Steel, 40 to 50 years have passed since many facilities were put into operation, and the necessity of renewing precision machinery equipment in all manufacturing processes has increased in recent years. Therefore, expansion of the application of the large block construction method was demanded.

To achieve the above-mentioned goal, technology development of a new construction method capable of satisfying both installation of precision machinery equipment, which requires machine installation accuracy of within ±0.1 mm, and handling of ultra-large and heavy objects, was necessary.

3.2 Development Concept of All Block Construction Method

In the conventional large block construction, mechanical equipment is manufactured in about 5 large blocks and then installed sequentially at the site. In contrast, the all block construction method is a method in which all mechanical equipment is preassembled off-line, and is then installed as one unit, as integrated machine equipment.

The technologies necessary in order to realize the all block construction method are shown below.

(1) Machine rigidity design technology considering hoisting of integrated machine equipment

Equipment design that quantifies the allowable values of deflection and stress generated when a set of machine equipment weighing more than several 100 t is hoisted, and reflects those values in equipment.

(2) Integrated handling technology for ultra-large and heavy machine equipment

Construction design that enables safe and stable equipment transportation by distribution of the large load generated when a set of machine equipment weighing more than several 100 t is transported.

3.3 Renewal of Entry Side Welder at Chiba 3TCM

3.3.1 Background

Chiba 3TCM (Tandem Cold Mill) is an automotive steel sheet production line that enables continuous cold rolling by butt welding the head end of the following strip to the tail end of the preceding strip by a laser beam welder (hereinafter, LBW). In the field of automotive steel sheets, there has been heightened demand for high tensile strength steel sheets with excellent strength properties that make it possible to reduce the thickness of steel sheets used in automobiles for auto body weight reduction. However, due to the limit of the equipment specification, the minimum sheet thickness for welding with the existing LBW was 1.8 mm. In order to respond to customers' requests for thinner high strength steel products, it was necessary to reduce the minimum welding thickness of the LBW to 1.0 mm. Therefore, a new LBW was introduced by one-set renewal of the existing LBW.

One important issue in this renewal was shortening of the continuous construction period requiring a line stop. Considering product deliveries to customers, it was essential to limit the continuous line stop (shutdown: hereinafter, SD) to no more than 10 days. Furthermore, the LBW is precision machine equipment which assures head-and-tail end butting accuracy of within 0.1 mm across the full width of product sheets. To achieve this target, technical development of the all block construction method was necessary, as a method that enables integrated installation of a large, heavy object while securing machine installation accuracy of 0.1 mm.

3.3.2 Conventional construction method and its issues

3.3.2.1 Outline of conventional construction method

In LBW renewal work at other plants until this time, the so-called parallel run method was adopted. In that method, the new LBW was installed in advance using empty space that was available immediately after the existing LBW, and production was then switched from the existing LBW to the new unit. This meant that the new LBW could be installed in several steps during regular SD for planned maintenance (hereinafter, regular maintenance or major regular maintenance) while continuing to produce products with the existing LBW. Because the construction work can be distributed over several steps in the conventional parallel run method, major regular maintenance could be kept to the normal period of about 4–6 days per maintenance period. Moreover, even after the new LBW was installed parallel run operation was possible by selecting either the existing LBW or the new LBW. This meant the impact on production could be minimized, even in trial operation to verify welding quality after installation of the new LBW.

3.3.2.2 Issues of conventional construction method

The Chiba 3TCM was put into operation in 1972 and was revamped as a fully-continuous line in 1988 by installing an LBW, looper and other equipment. No empty space was available due to presence of adjoining equipment both before and after this LBW. Since it was not possible to use the conventional parallel run method, renewal by a complete replacement method was necessary, that is, by first removing the existing LBW and then installing the new LBW at the same position. As an additional problem, threading equipment was located above the LBW. Due to this equipment arrangement, it was necessary to carry out incidental construction until restoration of operation after removing this upper equipment. Including the above work, the estimated continuous line SD for the renewal work was a long period of 31.5 days. An outline of the 3TCM line is shown in **Fig. 3**, and a comparison of the equipment layouts at 3TCM and the TCM at another plant is shown in **Fig. 4**.

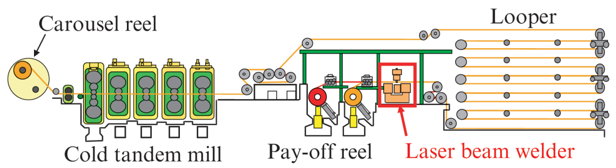

Fig. 3 Outline of 3TCM facilities

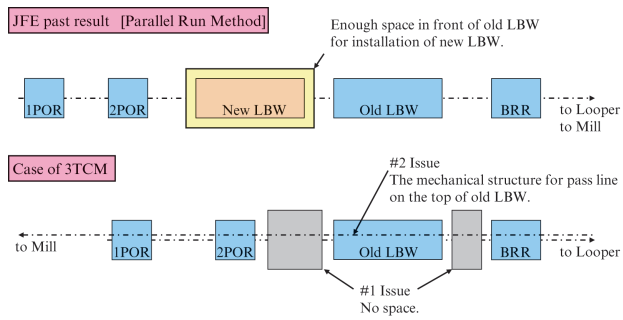

Fig. 4 Issue for the LBW setup

3.3.3 Technology development for all block construction method

To realize a radical reduction of the construction period from the continuous line SD of 31.5 days by the complete replacement method to 10 days, the following all block construction method technologies were developed.

(1) Improvement of threading equipment above the LBW as simple detachable structure
(2) Strength design of LBW body by new preassembled LBW hanging load
(3) Preassembled LBW installation method by joint hoisting with two overhead traveling cranes
(4) Shortening of trial operation by advance installation and startup of new LBW oscillator
(5) Establishment of welding conditions by advance offline installation of new LBW and welding tests

The paper introduces the above (1) and (2), which are related to the all block construction method for installation of the preassembled new LBW.

3.3.3.1 Simple detachable structure of threading equipment above LBW

The area above the LBW had been a second floor structure that included the return path for strips passing from the looper to the mill. There was idle equipment that was already out of use in the return path. Therefore, in order to hoist the preassembled LBW with the overhead traveling cranes, it was necessary to remove and then restore all of the idle equipment and the second floor deck frame above the LBW. This had been the largest factor in the extended construction period.

As preliminary work before the actual renewal, removal of the idle equipment was carried out in stages during each regular maintenance period. Accompanying this, it was also possible to improve the existing threading equipment to a simple type consisting of support rolls and a table. Although bolted joints had been used in the structure of the second floor deck frame above the LBW, this was improved to a pin joint structure in order to minimize the time required for removal and restoration during the actual construction. This offered the prospect of reducing the time for this work from the original estimate of 6.5 days to 0.8 days in the final plan.

3.3.3.2 Block installation method for new LBW

As conventional technologies using the block installation method in the cold rolling section, items with required accuracy of within ±10 mm, such as the line tanks of chemical solution equipment, are well known. However, the LBW in this renewal is a large-scale precision machine with a body weight of approximately 100 t and required accuracy of ±0.1 mm, and there was also a possibility that deflection or stress concentrations that occur during hoisting might damage its accuracy, which was adjusted in advance. Therefore, from the design stage, the rigidity of the LBW frame was increased and strengthening parts were adopted in the linear guides between the common base and the frame, considering preassembled installation. A dedicated hanging tool was designed, and stress was distributed by installing eight hanging points, and a design that included additional installation of a backup roller to prevent inclination of the C-carriage was also adopted. An FEM stress analysis of hanging of the preassembled LBW showed that the generated stress was less than the design allowable stress and the allowable elastic deformation of 0.1 mm or less which is shear cutting accuracy as a result of these measures. Offline trial hoisting was performed in advance, confirming that there were no balance abnormalities, and the strain of the linear guides was within the allowable value, at 0.09 mm. The new technologies are summarized in **Fig. 5**, an example of the FEM stress analysis results is shown in **Fig. 6**, and the elastic deformation of the linear guide is shown in **Fig. 7**.

Originally, it was assumed that online assembly of the LBW would require 4.5 days, but this preassembled installation method made it possible to complete all preliminary assembly offline. As a result, the time

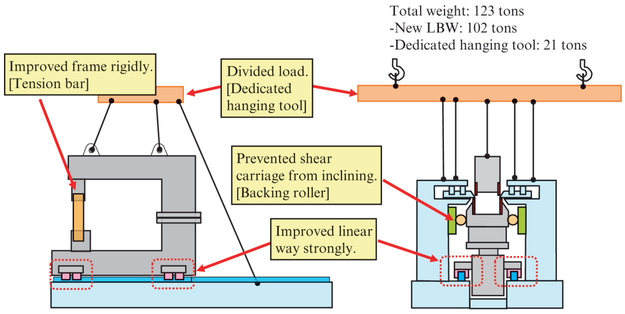

Fig. 5 New technology

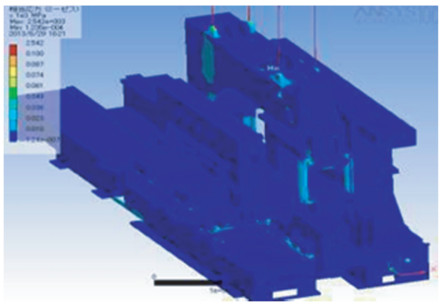

Fig. 6 Example of FEM analysis of deformation due to LBW weight

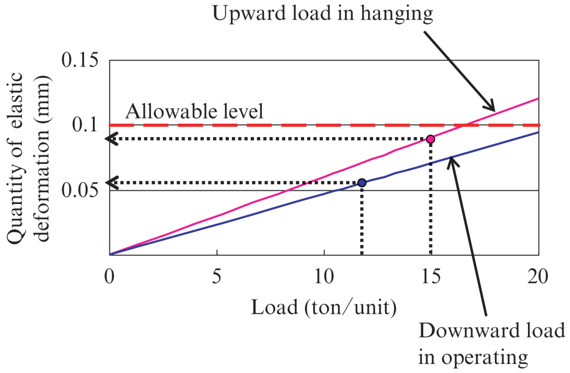

Fig. 7 Quantity of elastic deformation

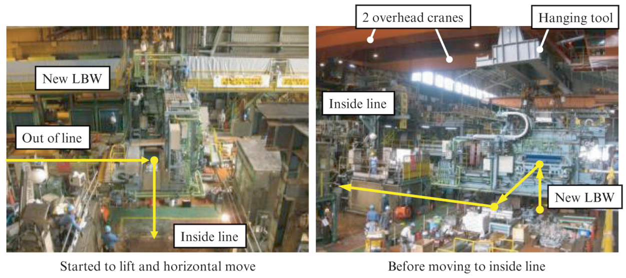

Photo 1 Actual hanging LBW of preassembled set

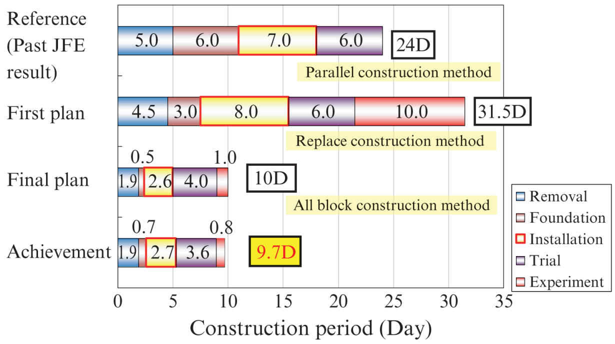

Fig. 8 Construction schedule table

required for assembly at the site during the actual construction period could be shortened to 2.2 days. In particular, the time from hoisting of the offline LBW as a preassembled set with the overhead traveling cranes until lowering to the online position and installation was only 2 hours. A photograph of the actual hanging of the preassembled set is shown in **Photo 1**.

3.3.4 Results

As a result of the technology development of the multiple items to shorten SD described above, the continuous line SD was reduced from the 31.5 days of the first plan to 10.0 days in the final plan. The actual time was 9.7 days, achieving the world’s fast LBW renewal. The construction schedule is shown in **Fig. 8**.

3.4 Renewal of Mill Housing at Kurashiki Plate Mill

In 2012, a mill housing post at the Kurashiki plate mill broke, and operation was restarted after repair by welding. Following this, renewal of the mill housing by the all block construction method was carried out in 2014 as a fundamental countermeasure for housing cracks.

Because the housing was to be replaced at the same position as the existing mill in this housing renewal work, it was necessary to stop the plate mill line for an extended period of time. Therefore, a drastic shortening of the renewal period by development of new technologies was demanded.

3.4.1 Conventional construction method

The construction method generally used in renewal of rolling mills is as follows. Using an existing overhead traveling crane or other equipment, the rolling mill is dismantled into its component parts and removed, after which the housing, which is the heaviest part, is removed. Next, the bed plate, which is the mounting plate for the new housing, is installed on the foundation, the housing is installed, and finally the component parts are mounted. **Figure 9** shows the conventional construction method.

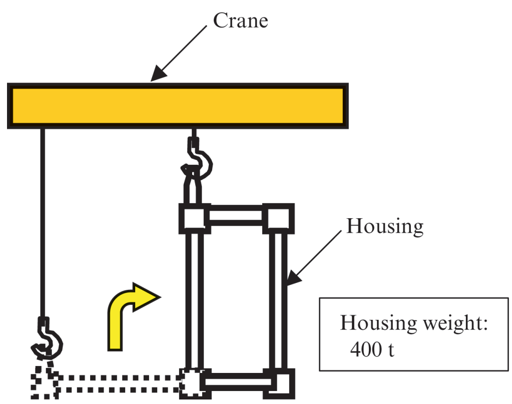

Fig. 9 Conventional renewal method

The housing, which weighs 400 t per unit, is raised and installed on the bed plate by using the overhead traveling crane. Its perpendicularity, line through core and orthogonal core are then adjusted so as to be within installation standard accuracy, after which the housing is fixed to the bed plate. Following this, the component parts of the mill are installed in order. This work requires a line stop of around 60 days.

3.4.2 Development of all block construction method for mill housing

In this renewal of the plate mill housing, the all block construction method was adopted in order to

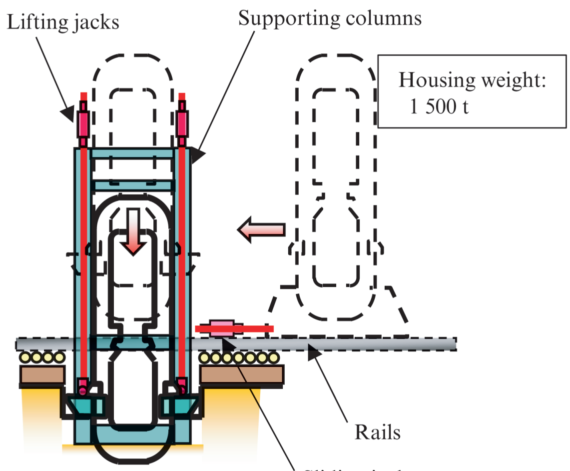

Fig. 10 All block construction method

Photo 2 Actual transporting housing unit

minimize the line SD. In this method, the mill stand was completely assembled offline, the preassembled unit was moved horizontally by sliding, and the mill was then installed as a single unit by jacking down.

Figure 10 shows an outline of the all block construction method.

In adopting the all block construction method, the following technologies were developed.

(1) Block dismantling technology for old housing
(2) Block sliding technology for new housing
(3) Block jack-down installation technology for new housing

This paper introduces (2) and (3), which are related to the all block construction method for the mill housing.

3.4.2.1 Block horizontal sliding technology

The housing unit, consisting of the housing, which weighs 400 t per piece, the housing mounting base (bed plate), and a separator connected to the upper part of the housing, were assembled on a temporary assembly stand, which was set up outside of the plant building and was also used as a transport carriage for the housing. In this process, the perpendicularity, line through core and orthogonal core were also adjusted so as to be within installation standard accuracy.

In order to move the housing unit as a single preassembled unit, it was necessary to develop a block sliding technology that would make it possible to move the ultra-large and heavy housing unit, which weighed 1 500 t including the supporting columns for jacking down, to the specified mill installation position quickly and safely.

The housing unit was moved on transport rails, which had been laid on the rolling mill table rolls, by sliding approximately 90 m using hydraulic sliding jacks.

The steel structure of the transport rails was designed so that the weight of 1 500 t was distributed on the rails, the generated stress did not exceed the allowable stress and deflection of the rails did not exceed the allowable value of 1/600. The time required for block sliding of the housing unit in this construction was only 3 hours.

A photograph showing the actual sliding transportation of the housing unit is shown in **Photo 2**.

3.4.2.2 Block jack-down installation technology

An outline of this technology is presented below. First, the housing unit, after transportation to the specified installation position by sliding, is supported by the hydraulic jacks of each of the supporting columns for jacking down, which are mounted on the unit in advance. Following this, the transport carriage and rails used in sliding are removed, and the housing unit is held in a suspended condition by the lifting jacks installed on the jack-down frame. The unit is then lowered to the leveling plates, which are arranged on the foundation in advance, by lowering the lifting jack, and installation of the housing unit is completed by tightening the foundation bolts.

As the lifting jacks for jacking down the housing unit, eight strand jacks were used. Since each of the strand jacks had eight wires with a diameter of 28.6 mm, synchronization control of the amount of lowering of a total of 64 wires was necessary. Synchronization control of lowering was possible by continuously detecting the amount of lowering by linear encoders attached to each wire, and controlling the hydraulic pressure of the wire chuck mechanisms so as to maintain a constant lowering speed at each wire.

In this construction, the horizontal accuracy during housing lowering was controlled to an inclination within 0.4 mm/m (target: within 0.5 mm/m), making it

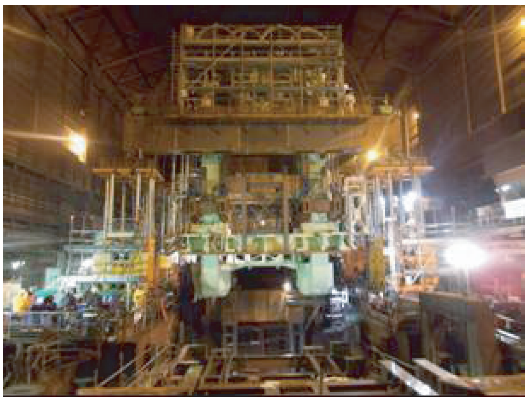

Photo 3 At the start of jack down

Photo 4 At the end of jack down

possible to install the housing unit while maintaining the accuracy of the preassembled unit.

A photograph at the start of actual jacking down is shown in **Photo 3**, and a photograph after the end of block jack down is shown in **Photo 4**.

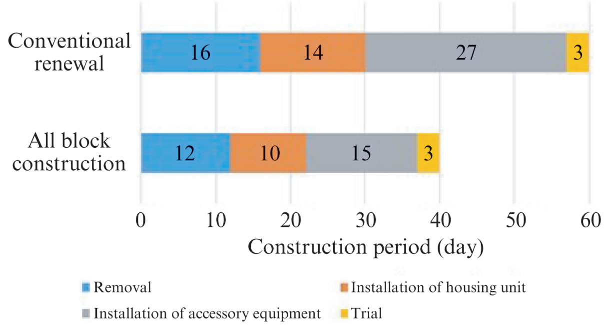

Fig. 11 Construction schedule table

3.4.3 Results

The development of the housing unit block transportation technology and the housing unit block jacking-down installation technology described above made it possible to shorten the line SD by 20 days in comparison with the conventional construction method, thereby achieving the world's fastest plate mill housing renewal with an actual SD time of 40 days. The schedule of this construction is shown in **Fig. 11**.

4. Conclusion

This paper introduced technologies for shortening the construction period in large-scale construction work at the steel works of JFE Steel Corporation. In the future, with the continuing renewal of aging steel works equipment accompanying advanced age and the development of new production equipment with higher accuracy requirements, we will actively promote the development of technologies for shortening the time required in construction work in order to ensure a stable supply of products to customers.

Reference

1) Fujita, M.; Tokuda, K.; Kojima, H. Short-Term Revamping Technology for Large Blast Furnace. JFE Technical Report. 2006, no. 8, p. 71–79.