Transition of blast furnace revamping technology, and challenge to a super-short term revamping technology

～Establishment of single-block method of revamping technology～

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Abstract

A blast furnace comes to the end of its life in 15 to 20 years after blowing-in, and restored by a revamping work. In conventional methods, it took 120 or more days to complete a revamping work but, in order to avoid the decrease of output during the revamping work; it had been a demand of the industry to reduce the term of a revamping work. In the year 2000, a large-block method was established, revamping work brought major changes. Even then, the term of revamping work was reduced to 68 days by the shortterm revamping technology advances in the year 2009. Due to further technical development, revamping work is successful in reducing to period 50 days by establishing super large-block method technology that blast furnace and structure are exchanged at single block.

Key word : Blast Furnace, Construction, Relining, Reconstruction, Replacement, Renewal, Erection, Single Block, Large Block, Upgradation, Enlargement

1 Introduction

The life of a blast furnace is generally about 15 to 20 years from the start of use. Blast furnaces that reach their use limit are subject to revamping (replacement of the furnace body).

The conventional revamping method for full renovation involves disassembling and installing the divided furnace body into rectangular pieces (hereinafter referred to as the "rectangular piece method"). The rectangular piece method requires at least 120 days for revamping a blast furnace even when work is conducted around the clock.

In response to the needs from customers for minimizing the production decrease during the revamping of a blast furnace, Nippon Steel & Sumikin Engineering has been studying ways to shorten the period required for blast furnace revamping.

Nippon Steel & Sumitomo Metal Engineering Technical Review 2010 Vol. 1 has illustrated our technology for shortening the blast furnace revamping period evolving from the large block method used during the fourth revamping of Blast Furnace No. 3 at Nagoya Works (hereinafter referred to "N3R (4)") of Nippon Steel Corporation (current Nippon Steel & Sumitomo Metal Corporation) in 2000. The technical article also describes a case in which a 68-day revamping period was realized in the fourth revamping of Blast Furnace No. 1 at Oita Works of Nippon Steel & Sumitomo Metal Corporation (hereinafter referred to as "O1R (4)") in 2009, using a method for pulling out the remaining content in the furnace with the furnace body (hereinafter referred to as the "integral hearth pullout"), and a technique for bricking up the hearth shell block in advance to transport the block while maintaining the brick quality as-is (hereinafter referred to as the "advance hearth brick assembly").

After that, we continued technology development for the reduction of the blast furnace revamping period. In March, 2016, for JSW Steel Dolvi No. 1 Blast Furnace in India, we successfully used a method involving the integral replacement of the furnace body and tower performed in order to meet the requirement for a short-term, large-scale increase of the furnace capacity. This paper describes the history of blast furnace revamping technologies and the super-short period revamping method conducted for JSW Steel Dolvi No. 1 Blast Furnace.

2 Changes in Blast Furnace Revamping Methods and History of Short-Term Revamping Technologies

Since the establishment of the large block method, development of the blast furnace revamping method has made great progress. The large block method was used in N3R (4) for the first time in 2000, marking a major turning point of the revamping method. After the subsequent progress of the construction technology, during O1R (4), we achieved a reduction of the revamping period to 68 days. Table 1 shows the transition of the ability of revamping methods used for actual blast furnaces.

Table 1: Transition of blast furnace revamping technology

		Oita Blast Furnace No. 1 3rd revamping	Nagoya Blast Furnace No. 3 4th revamping	Kimitsu Blast Furnace 4th 3rd revamping	Oita Blast Furnace No. 2 3rd revamping	Nagoya Blast Furnace No. 1 5th revamping	Oita Blast Furnace No. 1 4th revamping
Year of revamping		1993	2000	2003	2004	2007	2009
Days for revamping		124	93	88	79	83	68
Furnace capacity	Before revamping	4,125 m^3	3,424 m^3	5,151 m^3	5,247 m^3	4,650 m^3	4,884 m^3
	After revamping	4,884 m^3	4,300 m^3	5,555 m^3	5,775 m^3	5,443 m^3	5,775 m^3
Revamping method		Rectangle piece method	Large block method				
Hearth shell block disassembly		Blasting method			Integral hearth pullout method		
Hearth shell block			500 t	980 t	3,100 t	3,500 t	10,000 t
Brick assembly weight		No prepared brick assembly		80 t	1,348 t	2,350 t	2,500 t

2.1 Integral hearth pullout technology

2.1.1 Integral hearth pullout using jacks

The integral hearth pullout method was devised with the aim of shortening the period for removing the content in the furnace after the establishment of the large block method, and applied to the third revamping of Blast Furnace No. 2, Oita Works, Nippon Steel & Sumitomo Metal Corporation (hereinafter referred to as “O2R (3)”). The concrete foundation of the furnace body was cut while the furnace was operated. After the shutdown, the hearth shell block that weighed approx. 3,100 tons including the content was lifted using a hydraulic jack mounted near the furnace body. A sliding plate was inserted into the space created under the jacked-up hearth shell block, and was pulled out horizontally using a center hole jack (hereinafter referred to as “CHJ”) onto the temporary transfer frame placed at the side of the foundation.

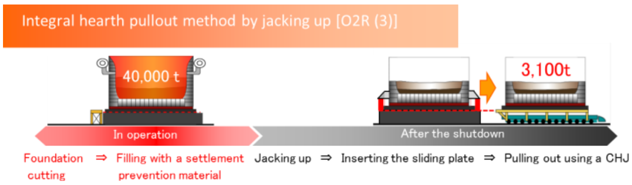

Fig. 1: Integral hearth pullout method by jacking up

2.1.2 Integral hearth pullout without the use of jacks

Since the above method using jacks has a limit on the weight that can be jacked up, an integral hearth pullout method was studied that does not use jacks but involves horizontally pulling out the hearth shell block without being jacked up. This method creates space in the concrete foundation of the furnace body, into which a sliding plate is inserted as shown in Fig. 3, and then a filling material is injected into the space above the sliding plate in order to support the load of the furnace in operation. The integral hearth pullout method without the use of jacks was adopted for the fifth revamping of Blast Furnace No. 1, Nagoya Works, Nippon Steel & Sumitomo Metal Corporation (hereinafter referred to as "N1R (5)"). This method has enabled the transportation of a blast furnace with an approx. 3,500 ton-hearth shell.

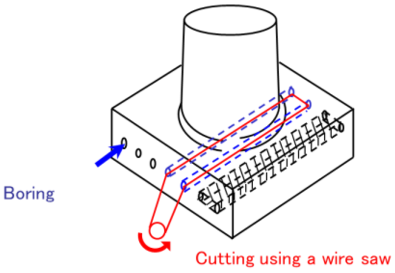

Fig. 2-1: Technique of cutting the concrete foundation

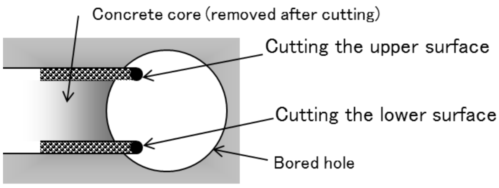

Fig. 2-2: Schematic view of 2-layer cutting

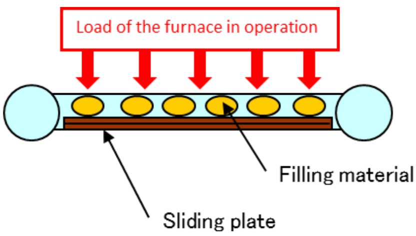

Fig. 3: Technique of supporting the load

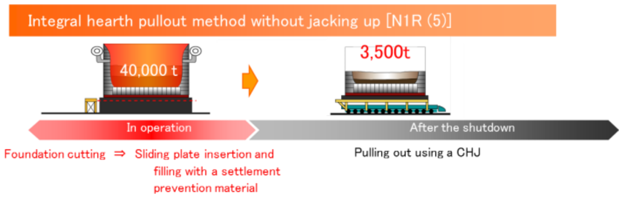

Fig. 4: Integral hearth pullout method without jacking up

2.1.3 Integral hearth pullout without the use of a dolly (Multi -axle dolly)

The integral hearth pullout without the use of jacks employs a dolly to transport the hearth shell block horizontally pulled onto the temporary transfer frame out of the furnace area. However, since the weight that can be carried by the dolly is limited, it is necessary to remove the content in advance until the weight is reduced to a level carried by the dolly before the hearth shell block is horizontally pulled out onto the temporary transfer frame. Given this, with the aim of reducing such content removal process, we devised yet another integral hearth pullout method to eliminate the use of a dolly. The method without the use of a dolly involves pulling out the hearth shell block onto a balance beam that will be horizontally pulled on the ground together with the hearth shell block using a CHJ out of the furnace area. During O1R (4), we were successful in moving an approx.10,000 ton-hearth shell block up to 120 m.

The development of the integral hearth pullout technology without the use of a dolly has eliminated the need for dangerous work to remove the content remaining in the blast furnace conventionally performed by blasting, contributing greatly to the safety.

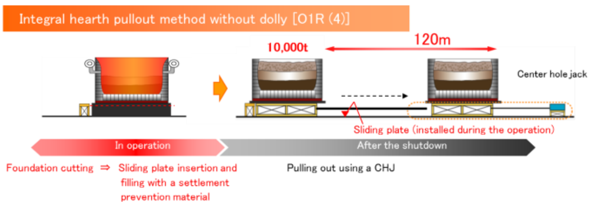

Fig. 5: Integral hearth pullout method without the use of a dolly

2.2 Advance hearth brick assembly technology

The advance hearth brick assembly technology involves assembling bricks on the hearth shell block at a site for base assembly, and transporting and installing the assembled shell block while maintaining the brick quality as-is, with the aim of shortening the brick assembly period in the blast furnace revamping. The assembled shell block can be transported mainly using the following two methods.

(1) Transfer by dolly from the base assembly site to alongside the furnace body foundation

(2) Transfer by compressed air rising from the side to the top of the furnace body foundation

Preventing the occurrence of defects on the assembled brick structure is required during the transfer by both methods. For method (1) by a dolly, an increase in the rigidity of the balance beam on which the hearth shell block is loaded can suppress the deformation of the shell block. For method (2) in transfer using a compressed air rising conveyor system, a technology for horizontally floating the shell block thereby suppressing the shell block deformation within the allowable range has been developed.

This technology was established in the third revamping of Blast Furnace No. 4 at Kimitsu Works of Nippon Steel & Sumitomo Metal Corporation (hereinafter referred to as “C4R (3)”). In subsequent revamping projects, the area and weight covered by the advance hearth brick assembly were increased. The development of a compressed air rising conveyor system with a capacity 1.5 times that of the conventional systems enabled the transportation of a hearth shell block with a total weight of 4,100 tons including the brick assembly weight of 2,500 tons during O1R (4).

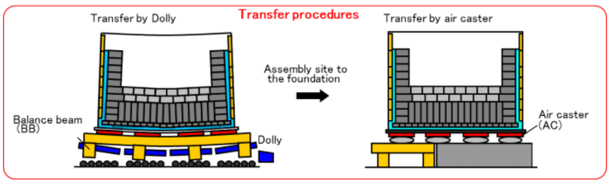

Fig. 6: Schematic view of transferring the hearth shell block

3 Attempt to Realize a Super-Short Revamping Period

3.1 Development of a super-short revamping method

When revamping Dolvi No. 1 Blast Furnace of JSW Steel (hereinafter referred to as “D1R”), the customer required that the renovation for increasing the furnace capacity for larger production be completed in a short span of time. As a result of an examination on the facilities, we concluded that it was necessary to increase the furnace capacity from 2,581 m^3 to 4,323 m^3 to achieve the production increase as desired by the customer, and the tower of the blast furnace also had to be renewed and enlarged.

The conventional large block method involves dividing the furnace body into four to five blocks that are temporarily suspended by a CHJ mounted on the existing furnace tower and then individually transporting them. The precondition for using this method is the use of the existing furnace tower. For this reason, if the large block method is adopted for D1R, the processes involving the disassembly of the existing furnace tower, installation of the new furnace tower, and installation of a CHJ would be critical as shown in Fig. 7, which made it difficult to complete the entire work in the short term. Therefore, we determined that the large block method was not suitable for the project.

Despite the difficult situation, in order to meet the strong desire of the customer to complete the blast furnace revamping process in a short span of time, we considered methods for short-term revamping using the conventional large block technologies and our own experience. As a result, we devised a world-first method involving integrally transporting the blast furnace body and tower (hereinafter referred to as the "single block method"). The customer approved our proposal to use this method.

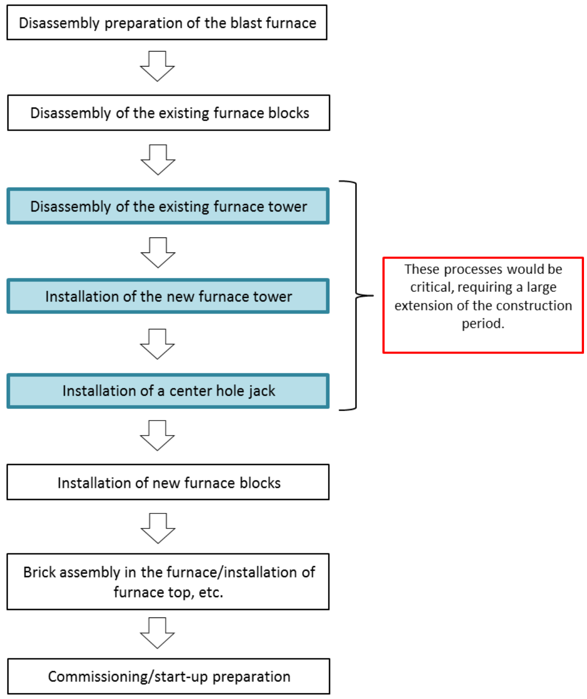

Fig. 7: Construction procedure for large-block method

3.2 Overview of the single block method

Figure 8 shows the concept of the single block method used during D1R.

For a new blast furnace, the work for the tower, blast furnace body and auxiliary equipment, and refractory in the furnace are finished near the existing blast furnace that is in operation. For the existing blast furnace, its foundation is cut while it is in operation in order to complete the disassembly preparation.

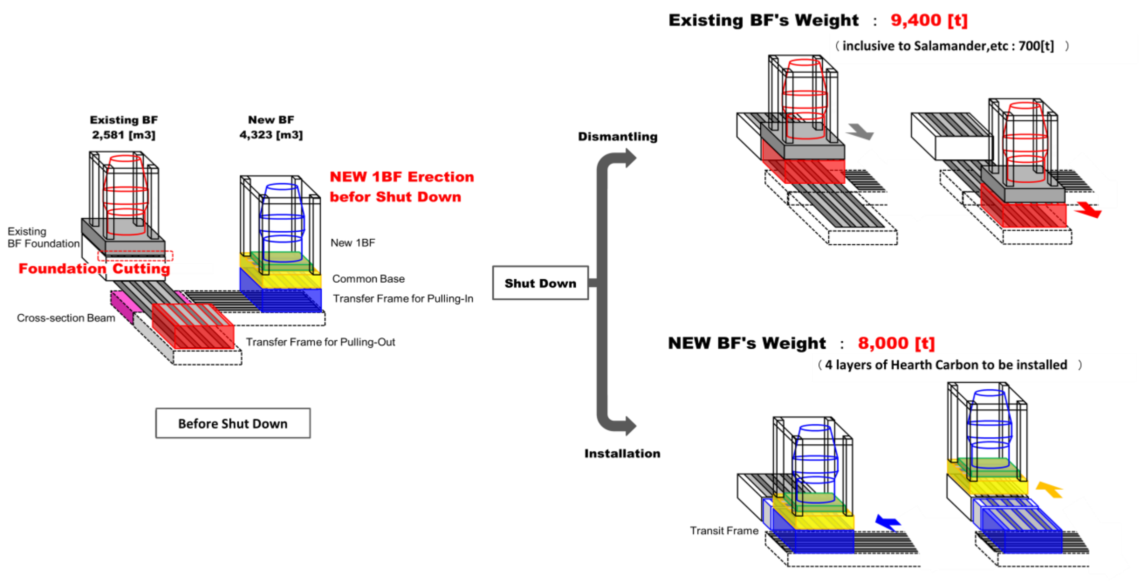

Fig. 8: Single-Block method

Following blowout of the existing blast furnace, after disassembly of furnace top, isolating and removing equipment that hinders the transfer of the furnace equipment, the integral hearth pullout without the use of a dolly was applied. The existing blast furnace (including the furnace tower and body as a whole) was moved onto the balance beam using a CHJ together with the cut foundation. Then, the existing furnace and transfer frame were moved together to the position where the transfer of the new blast furnace equipment was not hindered.

After finishing the pullout of the existing blast furnace equipment, the new blast furnace equipment built on the transfer frame near the existing furnace was moved together with the transfer frame to a position alongside the furnace foundation. Then, the blast furnace body equipment on the transfer frame was moved onto the furnace foundation. After the new blast furnace was placed at a specified position on the foundation, the furnace top equipment was installed and the blast furnace was connected to peripheral facilities. This was the final work of D1R.

In comparison with the 68 days that it took for O1R (4), the use of this single block method had effects of reducing by two days the disassembly preparation (effect from eliminating the block dividing), by four days for the existing furnace disassembly, by three days for the new furnace installation, by nine days for the brick assembly and furnace top equipment installation (effect from the advance hearth brick assembly). Thus, a reduction of 18 days during the entire revamping work can be expected from the use of the method. Thus, the days required for the blast furnace revamping are expected to be reduced to nearly 50 days using the single block method.

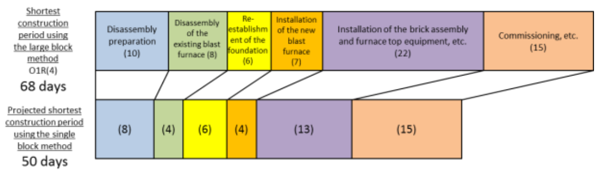

Fig. 9: Comparison construction period for revamping work
(Large-Block method, Single-Block method)

4 Overcoming the Difficulty in Using the Single Block Method

For practical use of the single block method, development of a new technology for transporting the existing and new blast furnace blocks was required based on our own technologies used in the conventional large block method, in view of the layout restrictions, and also the much larger size and weight of equipment to be transported than those of the equipment we had handled for furnace revamping previously.

4.1 Preliminary assembly of new furnace blocks

While the existing blast furnace is operated, the new blast furnace blocks are assembled in an area that will not hinder the existing blast furnace from being carried out of the furnace area. A common base shared by the blast furnace and tower is set on the transfer frame used for transporting the new furnace blocks, and the furnace body tower is built on the base. The furnace body equipment is assembled in several rings in advance, and is moved using a dolly to an area alongside the transfer frame. Each transfer consists of a horizontal one using a CHJ from the top of the dolly to the top of the base foundation, and lifting using another CHJ installed on the furnace tower. This process is repeated until the furnace body block assembly is completed.

Next, bricks are assembled inside the new blast furnace, while outside the furnace, floor decks, auxiliary equipment, and cooling pipes are installed at the same time. In addition, the bustle main and tuyere stock are installed. The installation of the equipment of the new furnace blocks is almost completed in advance. (Fig. 10)

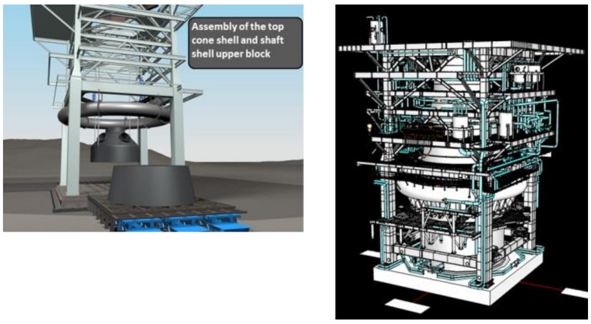

Fig. 10: Preliminary assembly for single block

4.2 Blast furnace block sliding rail structure

During the work under the single block method, the block weight becomes approx. 10,000 tons. The foundation of areas where the new furnace block is built and moved must be strong enough to bear the block load. Furthermore, the sliding rails must have highly horizontal accuracy to allow smooth sliding of the block on the foundation.

In the range in which the block moves, rails are installed on the foundation as shown in Fig. 11

with high accuracy, and concrete is placed in the periphery for obtaining sufficient strength. Plates that form the sliding surface are fixed on the rail after the levelness is adjusted, and the clearance is filled with mortar. The flatness accuracy of the installed plates for the travelling surface is within 5 mm. The joints of the plates are welded and by eliminating unevenness using a grinder, long distance travelling is enabled.

On the sliding surface between the sliding rail and the rail of the transfer frame for transporting the existing and new furnace blocks, a lining member with low frictional resistance is placed, thereby enabling easy and stable movement of even a very heavy object with very small force.

Furthermore, it is necessary to take measures for suppressing lateral displacement. This is because when the existing and new blast furnace blocks travelling on the rails laterally displace relative to the moving direction, the low friction lining installed under the transfer frame also shifts from the rails, disabling the stable movement. As a measure to solve this issue, as shown in Fig. 12, guide blocks are installed parallel to the moving direction. Forming a continuous guide trough on the side of the conveyor rails enables suppression of the lateral displacement. The installation of such guide block in two locations or more front and rear can secure stability and high accuracy of the furnace block movement.

Fig. 11: Sliding rail

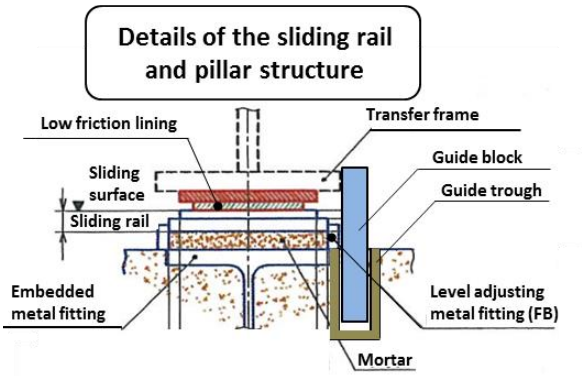

Fig. 12: Sliding mechanism & guide block structure

4.3 Switchover method from the existing furnace block to new furnace block

Due to the facility layout of the D1R site, the existing blast furnace block was linearly moved, but changes in direction were required during the transfer of the new blast furnace block because the new blast furnace block was placed in a position where the transfer of the existing furnace block was not obstructed as shown in Fig. 8.

We determined that the existing integral hearth pullout without the use of a dolly could be applied to the existing blast furnace block pullout in which the foundation was cut and the transfer frame was assembled while the existing blast furnace was in operation, and then the furnace was transported. However, there is a technical issue to be overcome regarding the transfer of the new blast furnace block, since this was our first attempt to change the moving direction in the middle of the block movement.

To overcome the issue, we devised a new preliminary assembly of the new furnace, in which the transfer frame was assembled on the transfer rails first, and the common base shared by the new blast furnace and tower was mounted on top of the transfer frame. Next, the new blast furnace and tower were assembled on the common base. As shown in Fig. 13, the new blast furnace block was pulled together with the transfer frame using a CHJ to an extension of the blast furnace center (primary pulling). At that time, a connection frame was set in the space between the new blast furnace block and the furnace foundation. The height of the connection frame was adjusted to that of the conveyor rails embedded in the furnace foundation before being connected to each other.

Then, as shown in Fig. 14, the connection frame was connected to the transfer frame for transporting the new blast furnace block. At that time, since the height of the transfer frame had been designed to be the same as those of the connection frame and furnace foundation, these parts could be connected at the same level, and the surface of these parts as connected could be used as the rail on which the block was moved. Subsequently, transportation of the new blast furnace block to a specified position on the furnace foundation was enabled by pulling the common base using a CHJ installed on the furnace foundation (secondary pulling).

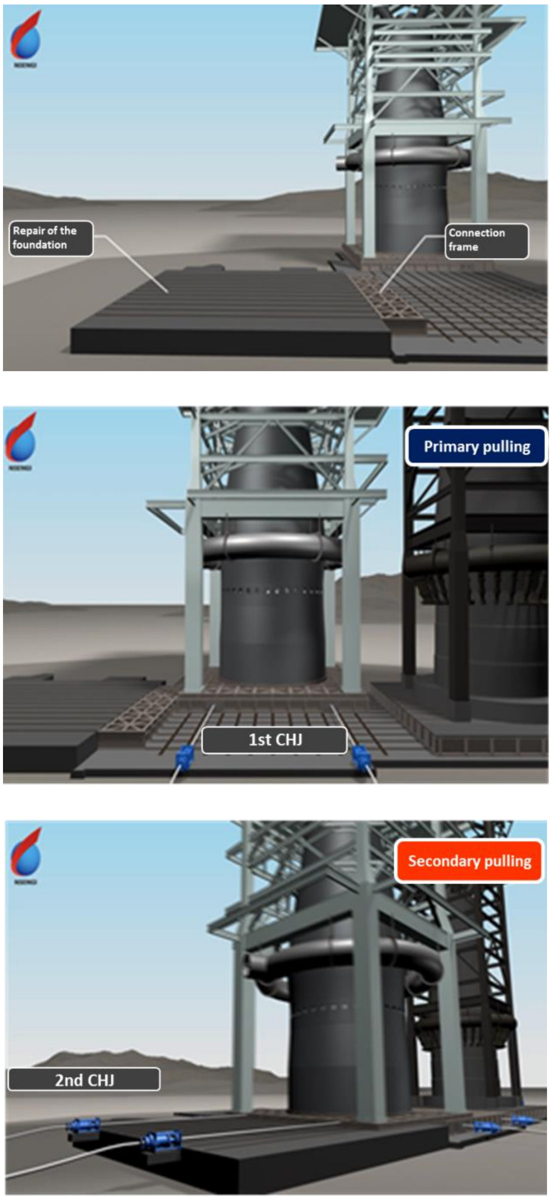

Fig. 13: New furnace block transferring method

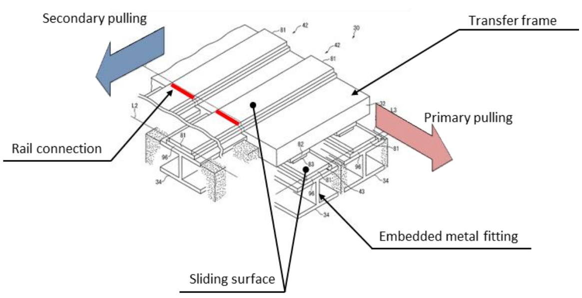

Fig. 14: Change-over method for new furnace block

4.4 Establishment of the single block method and future prospects

The single block method conducted for D1R was a new attempt at using our short period blast furnace revamping technology. The development and successful result of the new technology for the replacement of a structure approx. 50 m in height and approx. 10,000 tons in weight in a short span of time evolved from the existing short period revamping technology marked a great step forward in the development of our construction technology.

If this single block method is used to greatly increase the capacity of the blast furnace, the integral replacement of the furnace body and tower can be performed in a short term, significantly increasing the facility design freedom.

During D1R, the single block method was applied to the furnace body and tower. However, during future revamping projects, the integral transfer is expected to include not only the furnace body, but also the furnace top equipment. Furthermore, a further reduction of the construction period is also expected for this method.

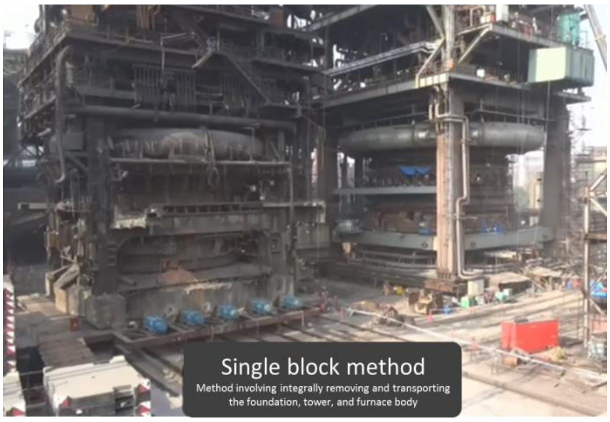

Fig. 15: Single-Block method records

5 Conclusion

In this paper, our past initiatives in the pursuit of shortening the blast furnace revamping period and the latest revamping technologies are described. Since the establishment of the large block method, we have developed heavy object transfer technology, which has led to significant progress in blast furnace revamping technology. The success of the latest single block method has enabled a reduction of the blast furnace revamping period to about half of that taken by N3R (4) during which the large block method was applied for the first time.

We will continue the efforts to further reduce the number of days required for blast furnace revamping in response to the customer's needs, using our accumulated technologies to shorten the construction period and develop new technology.