Steelmaking Technologies Contributing to Steel Industries

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st century will face a worldwide borderless society. Hence, the newly formed JFE Steel Corporation will develop new steelmaking processes and contribute to meeting diverse demands from around th world.

1. Introduction

NKK has continued to develop new steelmaking tech-

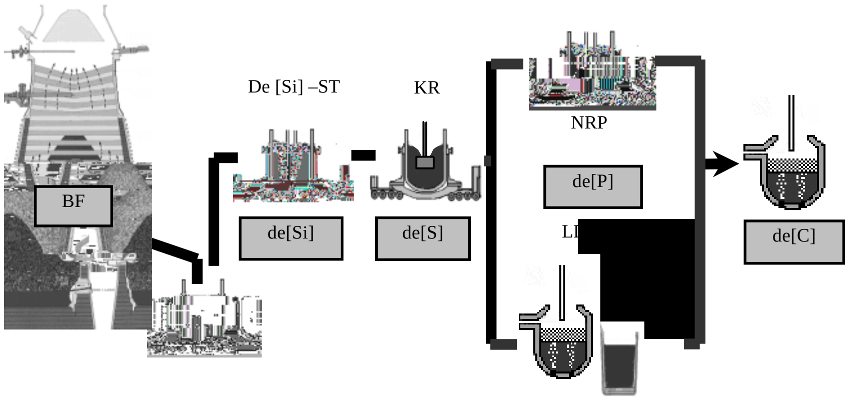


Fig.1　ZSP process flow at NKK's Fukuyama Works

siliconization. The reaction vessel is a ladle type, and the hot metal is vigorously stirred by injecting lime through a submerged lance. This method dramatically improved the oxygen efficiency for desiliconization over the conventional method of desiliconization, which is performed in hot metal runners on the cast-floor, and provides a highly efficient and stable supply of ultra-low silicon hot metal.

2.1.2　Hot metal dephosphorization technology

Experiments confirmed that reducing the silicon content of hot metal in turn lowers the amount of CaO that reacts with silica to form calcium silicate ($2CaO\text{-}SiO_2$) in the early stage of desiliconization. Instead, calcium phosphate ($3CaO\text{-}P_2O_5$) is formed directly. Also, a practical technology was established for performing the dephosphorization of the ultra-low silicon hot metal by controlling the oxygen flow rate and temperature. The reduced silicon content increased the efficiency of lime for dephosphorization, significantly lowering the lime consumption and stabilizing the phosphorous content in the hot metal after treatment.

At the Fukuyama No.2 steelmaking shop where the ladle-type dephosphorization process (NRP) is employed, the reduced slag generation retards the slag foaming phenomenon and other process-hindering factors. Hence, the extent of dephosphorization in the NRP was markedly increased by elimination of freeboard limitation in the hot metal transfer ladle.

On contrary, the LD-converter-type dephosphorization process (LD-NRP) has been in operation at the Fukuyama No.3 steelmaking shop since 1995. The LD converters in this shop are used as a decarburization furnace in the first half of their vessel life and then as a dephosphorization furnace in the latter half. Using ultra-low silicon hot metal, the dephosphorization furnace performs high-speed dephosphorization operation on all the hot metal that goes through this shop. This dephosphorization operation is synchronized with the tap-to-tap time of the decarburization furnace, to which the hot metal is then sent. The efficient high-speed dephosphorization achieved by these technological developments allowed an increase in the ratio of hot metal for which the dephosphorization operation can be applied. At Fukuyama Works, it is now possible to apply the ZSP to 100% of hot metal, even at the high production amount of 10 million tons per year. The average phosphorous content of hot metal after treatment is consistently less than 0.012%, allowing the decarburization furnace to be operated without the need of performing dephosphorization. Hence, flux consumption at the decarburization furnace was lowered to the minimum level required to protect the furnace refractories. **Fig.2** shows slag generation before and after the desiliconization station was installed. The slag, which was previously generated at a rate of more than 100 kg per ton of steel, was decreased by half. The slag generated in the converter dropped to less than 10 kg/t.

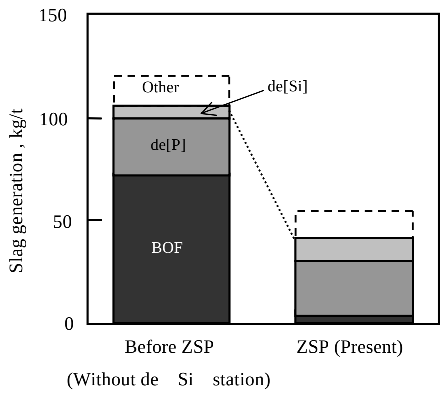


Fig.2　Effect of ZSP on slag generation

The lowered generation of slag brought about various additional benefits. The first is that the direct reduction of manganese ore in the converter became possible. Thus, ferromanganese consumption was markedly reduced. The second is that the life of the refractory lining of the converters was extended from 3000 charges to 8500 to 9000 charges. In addition, the ZSP had a large effect on improving the quality of the steel produced, such as a significant reduction in the generation of alumina, as described later.

Further, the compositions of the slags were simplified, which expanded their effective uses. As also described later, slag from desiliconization is now used effectively as potassium silicate fertilizer, while slag from dephosphorization is formed into large blocks by carbonation for constructing artificial fishing reefs. These slag products have been commercialized by NKK as environmentally friendly products that open the way to the next-generation steelmaking process.

2.2 New converter technologies

2.2.1 High-speed blowing technology

In the 1980's, a top-bottom-combined blowing technology (NK-CB) was developed by NKK for steelmaking converters[2)]. Next, the development of the ZSP described above turned a converter into a decarburization furnace that can effectively perform direct reduction of manganese ore[3)]. Major problems associated with this operation were iron spitting during oxygen blowing due to the minimized slag volume, decreased iron yield due to the increased dust generation rate, and unstable furnace operation. These problems hindered the realization of high-speed blowing for increasing productivity. NKK achieved high-yield, high-speed blowing by developing new technologies, as listed below, and shortened the blowing time by about 25%. As a result, the steel-producing capacity of one furnace (in the Fukuyama No.3 steelmaking shop) was increased to more than 480000 tons per month, contributing greatly to the increase in productivity.

2.2.2 New stainless steel refining process

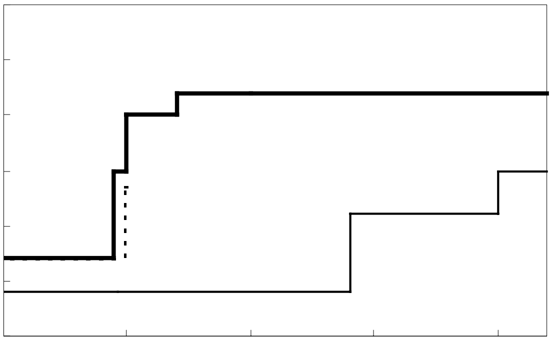
A new stainless SRF (Steel Refining Furnace) was started up in Fukuyama Works in September 1990 to reduce the production cost of the stainless steel[6]. This process is characterized by epoch-making technology, wherein refining is performed by repeatedly using a single converter, and nickel ore and chromium ore are directly reduced in the furnace. The production flow of austenitic stainless steel is schematically shown in **Fig.5**. Using hot metal as the primary material, Ni-containing hot metal is produced by the reduction of nickel ore. Next, dephosphorization is performed by the aforementioned hot metal pre-treatment facility. The material is then charged again into the converter, where Cr- and Ni-containing hot metal is produced by the reduction of chromium ore. After the hot metal and slag are tapped from the converter, the hot metal is charged into the converter once again, and oxygen is blown for decarburization. Lastly, RH degassing or the other secondary ladle refining technique is carried out for adjusting the final steel composition.

A horizontal, hot cyclone dust separator incorporated in the off-gas dust catcher recycles dust by separately recovering nickel and chromium from the dust. Thus, high-yield, stable operation was achieved using crude ores, and the technology was established for producing high-quality stainless steel at low cost.

Fig.5 Process flow of new stainless steel refining process

2.3 Secondary refining technology

In recent years, the necessity for developing high-



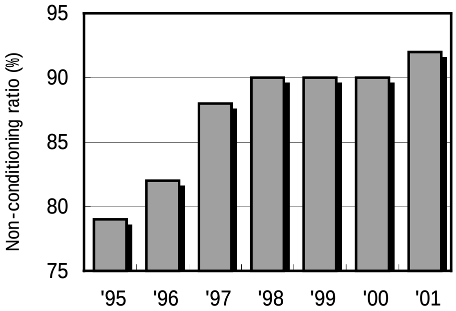
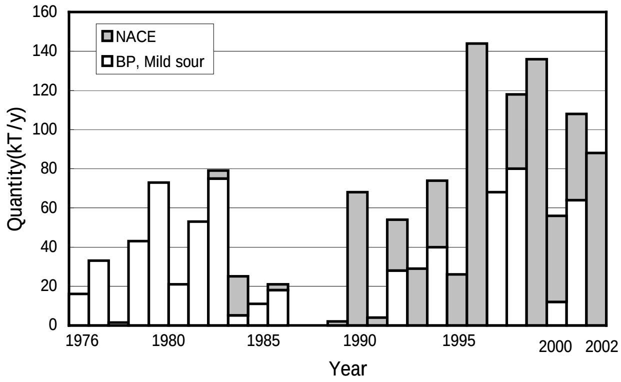


Fig.11 Slab non-conditioning ratio

Soft reduction casting technology was developed for casting slabs for producing steel plates and line pipe materials and commercially applied to reduce center segregation[19]. Center segregation is caused by the fluidity of solute-enriched molten steel due to shrinkage that takes place in the final stage of solidification. Narrowing the gap of the guide rolls at the final stage of solidification to compensate for the solidification shrinkage prevents center segregation by applying soft reduction to the slab, which suppresses the fluidity of the partially solidified steel. This technology effectively mitigates not only the continuous


NACE
BP, Mild sour
Quantity(kT/y)
Year
1976
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140
160