Technology

Application of High Efficiency Electrolytic Descaling Technology to the Cold Rolled Stainless Steel Continuous Annealing and Pickling Line

Masayuki SAKURAI* Atsushi OKAMOTO
Satoshi SAMPEI Toru MATSUHASHI
Masahiro TAKAHASHI

Abstract

In order to maintain high surface quality by improving the descalability, high efficiency electrolytic pickling technology has been applied to the cold rolled stainless steel #1 continuous annealing and pickling line of Kashima Works, Nippon Steel Stainless Steel Corporation (No. 1 APL). As a result, the descaling process, which previously required multiple processes, can now be eliminated in a single process, resulting in improved productivity and cost improvements.

1. Introduction

The cold strip mill at the Kashima Works of Nippon Steel Stainless Steel Corporation mainly manufactures hot-rolled stainless steel sheets and cold-rolled ferritic stainless steels. To survive the competition with the stainless steel manufacturers in rapidly growing Asian countries in recent years, we must pursue higher quality and achieve higher productivity and lower cost while responding to diversifying product lines.

Figure 1[1)] shows the equipment layout of the continuous annealing and pickling line (No. 1 APL) after cold rolling, one of the main cold-rolled stainless steel manufacturing processes at the Kashima Works. Stainless steels include various types from the low-grade SUH409 (11Cr steel) to the highly corrosion-resistant SUS329J4L (25Cr-6Ni-3Mo). When steel is heat treated, a complex and dense oxide scale composed of Fe, Cr, Si, etc. is formed on its surface. The descaling capacity greatly changes with the type and content of alloying element added. This complicates the descaling process. Industrially, the salt process of pickling a steel strip after immersing it in an alkaline molten salt has long been applied.

The No. 1 APL started operation in 1969. Its descaling equipment includes an alkaline molten salt immersion tank for pretreatment, and an electrolytic pickling tank mainly containing a sodium sulfate aqueous solution and an immersion tank containing a nitric acid aqueous solution or a nitric-hydrofluoric acid mixed aqueous solution (hereinafter referred to as a nitric-hydrofluoric acid aqueous solution) for finish descaling. This equipment configuration is designed to process all types of stainless steels on the same line.

Salt tanks are high in running cost and have the problem of

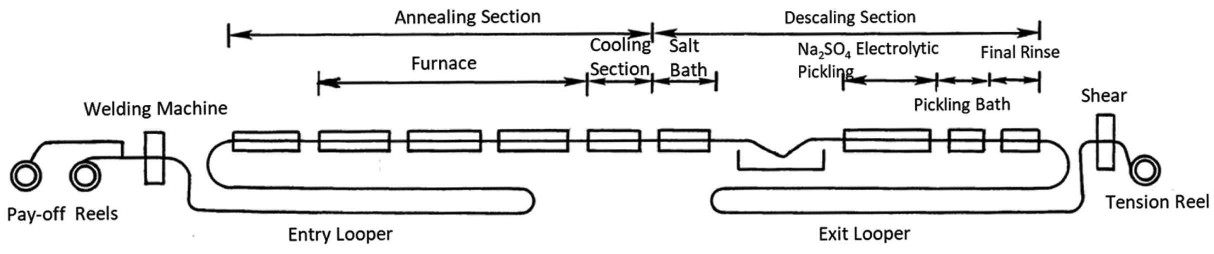

Fig. 1 Layout of Kashima Works No. 1 APL[1)]

* Manager, Cold Strip Technical Dept., Kashima Works, Production Division, Nippon Steel Stainless Steel Corporation
2-1 Hikari, Kashima City, Ibaraki Pref. 314-0014

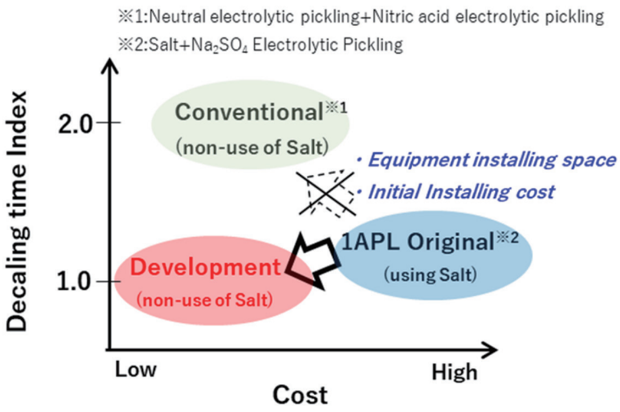

Fig. 2 The concept of development

chronic occurrence of roll marks. As a pretreatment to replace the salt process, a neutral salt electrolytic pickling process[2, 3] was developed and is now a mainstream process for annealing and pickling (AP) lines newly installed after the 1980s.

Figure 2 conceptually shows the descaling cost and time of descaling processes. Generally, the neutral salt electrolytic pickling process requires a longer descaling time and pickling tank length than the salt process. It is difficult to introduce the neutral salt electrolytic pickling process into lines already equipped with salt tanks like the No. 1 APL in view of equipment space and cost requirements. To have salt-free descaling equipment while maintaining the characteristics of the No. 1 APL that can process all types of stainless steels on the same line, we had to introduce descaling technology with descaling capacity twice or more that of the general electrolytic pickling processes. To achieve this goal, we diligently worked on the development and introduction of a high-efficiency electrolytic descaling process. The high-efficiency electrolytic descaling process can clean general-purpose ferritic stainless steels like the SUS430 with good surface quality. It combines an electrolytic descaling process with a salt process. We consequently achieved productivity improvement, cost reduction, and quality improvement. In this paper, we outline the high-efficiency electrolytic descaling technology (called the SEED process).

2. Conventional Descaling Processes in Finish Annealing and Pickling Lines

Conventional descaling processes in finish annealing and pickling lines generally combine pretreatment by salt immersion or neutral salt electrolytic pickling with descaling by nitric acid electrolysis or nitric-hydrofluoric acid immersion.

With the salt process, a mixed salt of sodium hydroxide and sodium sulfate is heated and melted at 450 to 500°C. The annealed stainless steel strip is immersed in a salt bath and descaled. The Cr-based oxide scale Cr_2O_3 and oxide scales such as Si oxide are removed with high efficiency.

The neutral salt electrolytic pickling process,[2, 3] a pretreatment process that does not use the salt process, descales the steel strip in an aqueous solution of sodium sulfate by alternating current electrolysis in which anodic electrolysis and cathodic electrolysis are alternately repeated in an aqueous solution of a neutral salt such as sodium sulfate. During the anodic electrolysis, the Cr-based oxide scale Cr_2O_3 is oxidized by the water-soluble $Cr_2O_7^{2-}$ ions and removed. Because the descaling capacity is inferior to that of the salt process, the descaling of equipment takes a long time. Also, oxides that do not dissolve in the acidic to neutral range, such as Si oxide, cannot be removed.[4]

Neither the salt process nor the neutral salt electrolytic pickling process can singly descale the steel strip completely. The remaining scale is removed by a subsequent descaling process. Ferritic stainless steel is required to have surface glossiness and cannot be finish pickled by the nitric-hydrofluoric acid immersion process, unlike austenitic stainless steel. The nitric acid electrolytic pickling process cannot be used for finish pickling of ferritic stainless steel. The nitric acid electrolytic method must be used instead. The nitric acid electrolytic pickling process descales the steel strip by alternating current electrolysis in which anodic electrolysis and cathodic electrolysis are alternately repeated in a nitric acid aqueous solution. During the cathodic electrolysis, the Fe-based oxide scale Fe_2O_3 is reduced to the Fe^{2+} and removed.[3]

These descaling processes each need pretreatment by the salt process or the neutral salt electrolytic pickling process and subsequent finish treatment.

3. Outline of High-Efficiency Electrolytic Descaling Process (SEED Process)

We investigated the high-efficiency electrolytic descaling process (the SEED process) without need for pretreatment, unlike conventional descaling processes, and considered its application to the No. 1 APL.

We conducted various studies on the SEED process based on potential-pH diagrams[5] and developed the optimum electrolysis conditions in which the Fe oxide and Cr oxide could be removed in one electrolytic pickling tank with high efficiency.

Photo 1 shows the appearance photographs of a specimen descaled by the conventional process without the salt process of the No. 1 APL and of a specimen descaled by the SEED process. The conventional electrolytic pickling process of the No. 1 APL could not remove all the scale, but the SEED process removed all the scale completely and the resultant surface quality was equivalent to that obtained with the conventional process. We confirmed that the SEED process can singly descale strips of general-purpose ferritic stainless steels like the SUS430 and can improve the descaling capacity while maintaining the surface glossiness.

Figure 3 compares the general-purpose ferritic stainless steel descaling time of the SEED process with the conventional descaling process consisting of neutral salt bath electrolytic pickling and nitric acid electrolytic pickling. The descaling time is calculated from the relationship between the electrolytic pickling tank length and the maximum line speed. The descaling time of the SEED process is one half or less of that of the conventional process. The SEED process is extremely efficient, low in running cost and capital investment cost, and highly competitive.

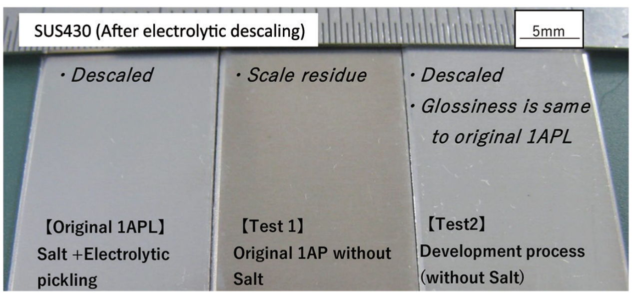

Photo 1 The surface appearance of the SEED process

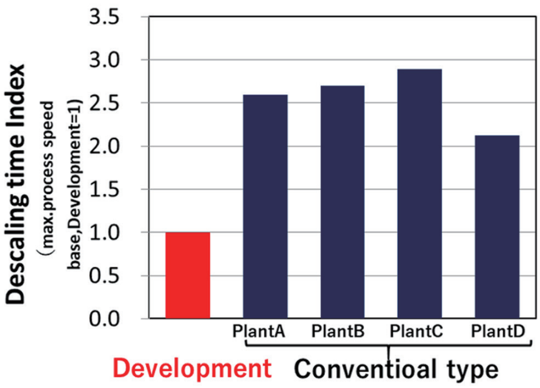

Fig. 3 The comparison of descaling time between the SEED process and the conventional pickling method (Neutral electrolytic pickling+Nitric acid electrolytic pickling)

4. Actual Application Results

We introduced the SEED process into the electrolytic pickling tank of the No. 1 APL and confirmed that the SEED process can provide good surface quality for general-purpose ferrite stainless steels like the SUS430. With the SEED process, we succeeded in reducing the pickling tank cost and improving the steel surface quality. (Some of the results are shown in **Fig. 4**). We also confirmed that the SEED process can improve the descaling capacity and speed for stainless steels conventionally pickled by the salt process.

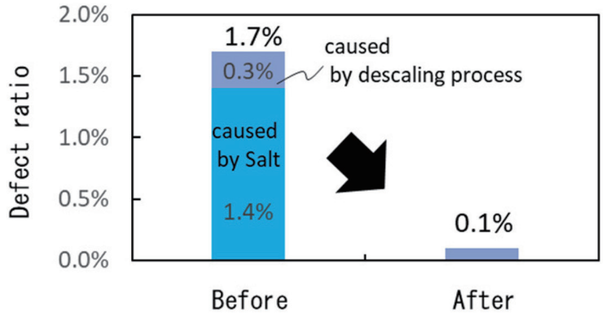

Fig. 4 Reduction effect of the defects caused by salt bath and descaling process due to the SEED process (SUS430)

5. Conclusions

We practically applied the high-efficiency electrolytic descaling process (the SEED process) to the electrolytic pickling tank of the No. 1 APL. We achieved both salt-free electrolytic descaling and salt descaling with the existing equipment and succeeded in reducing the salt descaling equipment cost, improving the descaling quality, and increasing the descaling speed. The SEED process is predominantly more efficient than conventional salt-free descaling processes and highly competitive.

We will continue our research and development efforts to achieve even higher stainless steel descaling efficiency.

References

1) Kano, Y. et al.: Japan Stainless Technical Report. (24), 145 (1989)
2) Hata, K. et al.: Hitachi Review. 58 (9), 7 (1976)
3) Yamaguchi, T. et al.: Hitachi Review. 72 (5), 45 (1990)
4) Kiya, S. et al.: J. Surf. Finish. Soc. Jpn. 47 (4), 41 (1996)
5) Pourbaix, M.: Atlas of Electrochemical Equilibria in Aqueous Solution. Pergamon Press, 1996


Masayuki SAKURAI
Manager
Cold Strip Technical Dept.
Kashima Works, Production Division
Nippon Steel Stainless Steel Corporation
2-1 Hikari, Kashima City, Ibaraki Pref. 314-0014


Toru MATSUHASHI
Chief Researcher
Function Creation Research & Development Div.
Research & Development Center
Nippon Steel Stainless Steel Corporation


Atsushi OKAMOTO
Cold Strip Technical Dept.
Kashima Works, Production Division
Nippon Steel Stainless Steel Corporation


Masahiro TAKAHASHI
General Manager, Superintendent
Cold Strip Mill
Kashima Works, Production Division
Nippon Steel Stainless Steel Corporation


Satoshi SAMPEI
Senior Researcher
Kyushu R & D Lab.
R & D Laboratories
Nippon Steel Corporation