Improving the Surface Quality of Ultra-High Efficiency Electrical Steel Slabs for Grade 25CS1250HF in the Continuous Casting Process

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Ultra-high efficiency electrical steel slabs for grade 25CS1250HF in China Steel Corporation are mainly supplied to the United States, Germany, and Japan for use in electric motor cores for the world's leading automobile manufacturers. In the past, the sliver defect rate of hot rolled coil from steelmaking for grade 25CS1250HF was 2.64%. Surface quality issues seriously affected the yield of finished products. Through observation and investigation of the steelmaking defects on the hot rolled steel coil surface, it was found that severe sliver defects occurred mainly in the early stage of the continuous casting process. The Energy-dispersive X-ray spectroscopy(X-EDS) analysis results showed that the sliver defects were caused by the slag from casting powder during the continuous casting process. The investigation results showed that increasing the molten steel superheat, lowering the cast speed at the beginning of the continuous casting process, and carrying out machine scarfing for slabs with low superheat is beneficial in reducing the occurrence of sliver defects on the steel coils for ultra-high efficiency electrical steel. After stable production and application, the sliver defect rate of the hot rolled coils for the ultra-high efficiency electrical steel slabs for grade 25CS1250HF was improved significantly. The sliver defect rate of the hot rolled coil was reduced from 2.64% to 1.25%. In particular, the sliver defect rate of hot rolled coil from cast starting slabs was reduced from 21.86% to 6.58%. This work overcomes the technical bottleneck in the continuous casting process of ultra-high-efficiency electrical steels for grade 25CS1250HF. This will facilitate the development of the electric motor industry and contribute to the global sustainability goal of net zero carbon emission.

Keywords: Ultra-high efficiency electrical steel, Sliver defect, Continuous casting process

1. INTRODUCTION

With the increasing concern for environmental regulations and energy-saving issues, the demand for high-grade and thin gauge electrical steel for new energy-saving vehicles and high-efficiency motors has grown significantly. In 2011, China Steel Corporation (CSC) started to develop thin gauge electrical steel with a thickness of less than 0.30 mm and successfully thinned to 0.20 mm.

The new non-grain-oriented electrical steel production line launched in 2014, enhanced the CSC's manufacturability for high-grade and thin gauge effectively. Based on the electrical vehicle customer's requirements for the thin-gauge, high-strength electrical steel, CSC assisted the customers in developing ultra-high efficiency electrical steel with low iron loss at high frequency and high magnetic flux density, 25CS1250HF, increasing the efficiency of electrical motors and reducing energy consumption.

Because of the forced hot-charging of electrical steel slabs into the furnace, the steel slabs cannot be offline inspected. Steelmaking defects are detected after the hot-rolling process, which increases the rolling production rework of hot-rolled coils. Therefore, in this work, the main purpose is to improve the slab quality. We investigated the root causes of steelmaking and adapted the continuous casting process parameters. To increase the hot rolled coil acceptance rate of the ultra-high efficiency electrical steel slab.

2. EXPERIMENTAL METHOD

2.1 Observation of Steelmaking Defects on Hot-Rolled Coils

The typical appearance of the steelmaking defects on the hot rolled coils was characterized mainly by sliver, which is a more serious case, with sliver dimensions of 20 cm in length and 1.9 cm in width shown in Figure 1. The sliver defects were mainly located at the head end of the hot rolled coil in the length direction and at the center of the top surface in the width direction.

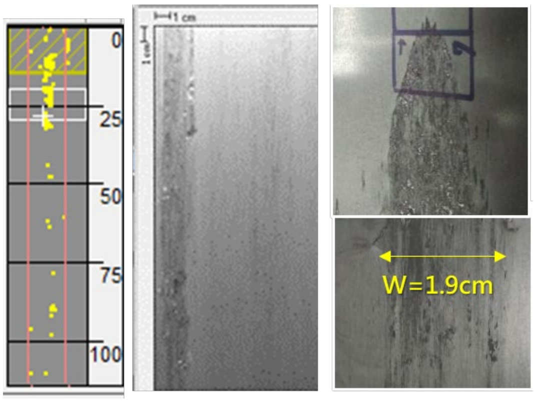

Fig.1. Typical steelmaking sliver defect on the surface of hot-rolled coil.

The metallographic analysis showed that the sliver defects were sub-surface multilayered inclusions, as shown in Figure 2, indicating that the sliver defects were formed by reciprocating rolling. The Energy-dispersive X-ray spectroscopy(X-EDS) analysis results show that the defects are mainly oxides of aluminum, silicon, and sodium, which are components of casting powder, and it is concluded that the defects are caused by the slag from casting powder during the continuous casting process.

2.2 Analysis of Influencing Factors of the Continuous Casting Process

The superheat of molten steel is an important parameter of continuous casting that affects the stability of the casting process. When the superheat is too low, the temperature of molten steel is close to its liquid phase temperature. This gradually causes molten steel solidification, the inclusions in the mold cannot easily be floated up and so are captured by the solidification slab shell during the continuous casting process and remain in the sub-surface of the slab, which will lead to the formation of sliver defects after hot rolling.

At the beginning of the continuous casting process, the casting speed increases from zero to the specified speed, the flow kinetic energy of molten steel increases rapidly and the flow field is not stable in the casting mold. If the casting speed is too high, some liquid mold slag might draw down along the outside of the submerged entry nozzle (SEN). Under severe conditions, the slag will become entrained into the molten steel jet, leading to the formation of sliver defects.

2.3 Control Method for Machine Scarfing Process

Machine scarfing proved a viable and common process for commercial steel grades to remove defects from the surface of slabs to improve the finished product. However, in the early stage of the development of ultra-high efficiency electrical steels, which are inherently brittle at low temperatures and low thermal conductivity. It was known that machine scarfing with high-pressure descaling water can remove the surface defects of slabs and prevent the re-oxidation of the slabs' surface. High-pressure descaling water also may accelerate the surface cooling and cause cracks on the surface of slabs. Thus, the implementation of machine scarfing for slabs of ultra-high-efficiency electrical steels shall be carefully evaluated.

On-site measurements are taken to track the slab temperature history to ensure that machine scarfing can be performed within 30 minutes after the steel slabs are released from the casting strand. The surface temperature of the slabs can still meet the requirements for hot-charging into the furnace. After the steel slabs via machine scarfing are manufactured into hot rolled coils and finished coils, the coils are inspected to make sure that no additional defects are caused on the surface. Finally, machine scarfing for slabs of ultra-high-efficiency electrical steels is included in the routine treatment.

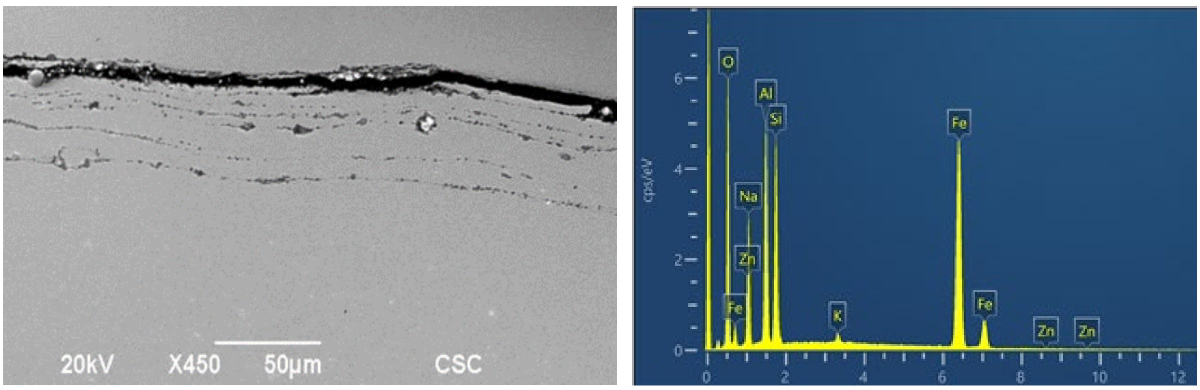

Fig.2. Metallographic analysis and X-EDS analysis of sliver defects.

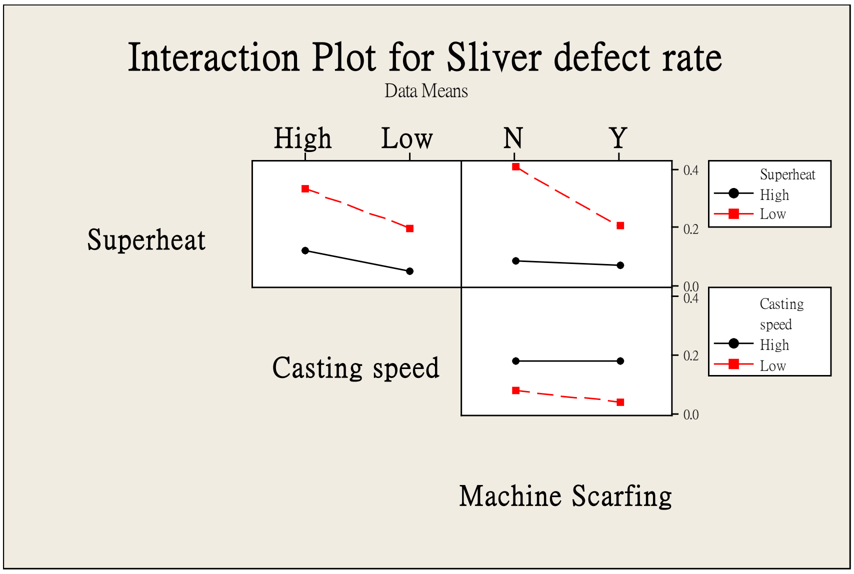

Fig.3. Minitab software analysis results of sliver defect rate.

3. RESULTS AND DISCUSSION

The experimental results and the statistical results of Minitab are shown in Figure 3. The results show that increasing the molten steel superheat, lowering the cast speed at the beginning of the continuous casting process, and carrying out machine scarfing for slabs with low superheat is beneficial in reducing the occurrence of sliver defects on the steel coils for ultra-high efficiency electrical steel.

After adjusting and stabilizing production, the sliver defect rate of the hot rolled coil for the ultra-high efficiency electrical steel slabs for grade 25CS1250HF was improved significantly, the sliver defect rate was reduced from 2.64% to 1.25%. In particular, the sliver defect rate of hot rolled coil from casting starting slabs was reduced from 21.86% to 6.58%.

4. CONCLUSIONS

CSC has achieved successful improvement in the surface quality of ultra-high-efficiency electrical steel slabs for grade 25CS1250HF in the continuous casting process.

The surface quality issues of the 25CS1250HF steel with steelmaking defects are caused by the slag from casting powder during the continuous casting process. The molten steel superheat and the casting speed are key factors in the formation of sliver defects.

After application of the optimized process parameters, increasing the molten steel superheat, lowering the cast speed at the beginning of the continuous casting process, and carrying out machine scarfing for slabs with low superheat is beneficial in reducing the occurrence of sliver defects for ultra-high efficiency electrical steel. These improvements have had a substantial positive effect on quality enhancement and increased production capacity in the manufacturing of ultra-high-efficiency electrical steel, enabling CSC steelmaking technology to keep progressing and further strengthening its position in the electric vehicle motor industry.

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