Traditionally most containers are made of hot-rolled coils of JIS G3125 SPA-H specification or the like. In response to the global new trend of environmental protection, CSC has developed a new generation of ACR-TEN 550Y hot-rolled coil for container use.

CSC ACR-TEN 550Y is featured with high yield ratio, high tensile strength, and good atmospheric corrosion resistance. The higher strength that can make container stronger and thinner to decrease weight and save energy and cost is achieved using the mechanism of precipitation hardening and fine-grain microstructure by adding some microalloy elements in the design of the chemical composition.

Good atmospheric corrosion resistance that can prolong container’s life cycle is attributed to the addition of P, Cu and Cr. Good weldability that can make welding performance better is promoted by lower [C] and lower [S]. In summary, with multiple functions, the high strength CSC ACR-TEN 550Y steel is expected to gradually replace JIS G3125 SPA-H as a new material for container use.

**Key words:** container, weather resistance, high strength, weldability.
1 Introduction

Corten steel, developed and trademark registered by U.S. Steel, is a generic term for the steel possessing the characteristics of high strength and corrosion resistance to weather and also called Weathering steel. It refers to the specifications including ASTM A242, ASTM A588, JIS G3125 SPA-H, EN 10025-5 S355J0WP, CSC ACR-TEN⋯, which contains [P], [Cr], [Cu] and other weathering elements to form particular rust on the surface as a protecting layer and therefore can be exposed in the atmosphere without coating.

One of the most common applications of Corten steel is the manufacture of containers as they are shipped and transported from land to ocean environment frequently, and so need to be strong enough to protect internal cargo from damage and to possess the corrosion-resistant capability to increase life cycle. Although the existing specifications are suitable, a more energy-saving material is expected to cope with the trend of global environmental protection. Being a responsible steelmaker, recently CSC has developed hot-rolled steel CSC ACR-TEN 550Y with a higher strength compared with other CSC ACR-TEN steels in Table 1. CSC ACR-TEN 550Y may reduce the container weight to reach the purpose of saving energy.

CSC ACR-TEN 550Y is characterized by the microstructure consisting of a fine ferrite matrix that leads to higher strength of $YS \geq 550\text{MPa}$ and $TS \geq 590\text{MPa}$ while keeping good formability. This article will introduce the control strategies of metallurgy aspects mainly on chemical compositions, rolling process, and corrosion resistance performance.

Table 1. Chemical composition and mechanical property of CSC ACR-TEN Specification

<table>
<thead>
<tr>
<th>Grade</th>
<th>Applicable Thickness Range (mm)</th>
<th>Chemical Composition (%)</th>
<th>Tension Test</th>
<th>Bendability</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>C</td>
<td>Si</td>
<td>Mn</td>
</tr>
<tr>
<td>ACR-TEN A</td>
<td>1.6~12.7</td>
<td>0.12 max</td>
<td>0.25</td>
<td>0.20</td>
</tr>
<tr>
<td>ACR-TEN AF</td>
<td>1.5~12.7</td>
<td>0.08 max</td>
<td>0.15</td>
<td>0.15</td>
</tr>
<tr>
<td>ACR-TEN 550Y</td>
<td>1.5~12.7</td>
<td>0.12 max</td>
<td>0.10</td>
<td>0.30</td>
</tr>
</tbody>
</table>

ACR-TEN naming method :
ACR : Atmospheric Corrosion Resistance
TEN : Tensile
F : Formability

2 Sample coil and evaluation test

2.1 Sample coil

The sample coil of 1.5mm in thickness was rolled from the 270mm thickness of slabs
made by BOF-LF process and continuous cast. The chemical composition of CSC ACR-TEN 550Y was designed such that Phosphorus, Chromium, and Copper were to enhance corrosion resistance, lower carbon and lower sulfur were for good welding performance, and the micro-alloy element of titanium was to obtain a fine-grain microstructure and the precipitation of titanium compound, as shown in Table 2.

<table>
<thead>
<tr>
<th></th>
<th>C</th>
<th>Mn</th>
<th>P</th>
<th>S</th>
<th>Si</th>
<th>Cr</th>
<th>Cu</th>
<th>Ti</th>
<th>Added</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max</td>
<td>0.12</td>
<td>0.80</td>
<td>0.050</td>
<td>0.005</td>
<td>0.60</td>
<td>0.70</td>
<td>0.45</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Min</td>
<td>0.06</td>
<td>0.30</td>
<td>0.020</td>
<td>--</td>
<td>0.10</td>
<td>0.40</td>
<td>0.25</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

2.2 Hot Rolling Processes

The experimental slabs were heated and soaked at 1150°C-1250°C, and then hot rolled in CSC #2 HSM. The profiles of the hot rolling processes are shown in Fig. 1. Reheated slabs were rolled to transfer bars by roughing mill and then rolled to strips by finishing mill. The finishing rolling temperature was within 800-950°C. After finishing rolling, coils were cooled by laminar flow. Coiling temperature was designed more than 550°C, depending on the thickness.

![Fig. 1. The profiles of the hot rolling process](image)

2.3 Microstructure Observation

Test specimens were taken at the quarter position of width, and test pieces were processed according to the standard metallographic procedures. The microstructure characteristics were observed using OM and SEM.

2.4 Tensile Test

Test specimens were taken at the quarter position of width, and JIS #5 tensile test pieces with size (25mm W * 50mm L) were used.
2.5 Corrosion Resistance Test

Corrosion resistance was tested by salt spray according to the standard of ASTM G85 A5. Test specimens with size (150mm W * 100mm L) were used and sprayed by 0.05% NaCl + 0.35% (NH₄)₂SO₄ (pH between 5.0~5.4) solution at room temperature. The weight loss of specimens was measured once a week for four weeks in total.

3 Results and Discussion

3.1 Microstructure and Mechanical Properties

The mechanical properties and microstructures of CSC ACR-TEN 550Y are shown in Fig. 2. and Table 3. The matrix is fine ferrite structure and a few amounts of carbide or pearlite precipitation in the grain boundary. Fine ferrite structure of CSC ACR-TEN 550Y leads to higher strength and good formability compared with other Corten steels, and the test results of CSC ACR-TEN 550Y could meet the requirement.

![Fig.2. Microstructure of CSC ACR-TEN 550Y](image)

**Table 3. Mechanical properties of different Corten steels.**

<table>
<thead>
<tr>
<th>Spec. Requirement</th>
<th>YS(MPa)</th>
<th>TS(MPa)</th>
<th>EL(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>JIS G3125 SPA-H</td>
<td>355 min</td>
<td>490 min</td>
<td>15~22 min</td>
</tr>
<tr>
<td>EN 10025-5 S355J0WP</td>
<td>355 min</td>
<td>470~510 min</td>
<td>14~20 min</td>
</tr>
<tr>
<td>CSC ACR-TEN 550Y</td>
<td>550 min</td>
<td>590 min</td>
<td>16~18 min</td>
</tr>
<tr>
<td>CSC ACR-TEN 550Y Test results</td>
<td>609</td>
<td>688</td>
<td>23</td>
</tr>
</tbody>
</table>
3.2 Corrosion Resistance Properties

The corrosion resistance test results were shown in Fig. 3. Product A with similar strength level of Corten steel was provided by the customer. Product A, SPA-H and CSC ACR-TEN 550Y were tested by salt spray method mentioned above. After four weeks, the weight loss of product A was more than that of CSC ACR-TEN 550Y and SPA-H. This result indicates the CSC ACR-TEN 550Y has better corrosion resistance than product A.

![Graph showing weight loss over test period](image)

Fig.3. Salt spray test results of Corten steels

4 Summary

The effects of chemical compositions, hot rolling parameters, and cooling parameters on the mechanical properties and the microstructures of hot-rolled CSC ACR-TEN 550Y steels were investigated, and the main points thereof were as follows:

(1) The CSC ACR-TEN 550Y exhibit high YS，TS and good EL properties, compared with the commonly used Corten steel SPA-H.

(2) To obtain better mechanical properties, especially for strength, the addition of micro-alloy of Titanium is helpful.

(3) An optimum combination of microstructure and mechanical properties can be obtained by suitable chemical design and hot rolling process.

In summary, featured with multiple functions, the high strength CSC ACR-TEN 550Y steel is expected to gradually replace JIS G3125 SPA-H as a new material for container use.

5 References