Development and application of free pretreatment container steel

Y Yang¹,²*, Y Liu², B Han², B Wei² and S Z Wang²

¹The State Key Laboratory of Rolling and Automation, Northeastern University, Shenyang 110004, Liaoning, China
²Wuhan Branch Baosteel Central Research Institute (Technology Center of Wuhan Steel Ltd.) Wuhan 430080, Hubei, China
*E-mail: yangyi_2008@aliyun.com

Abstract. Due to economic and environmental advantages pre-treatment containers have good big development prospects, which can avoid shot blasting processes, and decrease the noise and dust pollution. By analyzing requirements of the container steel surface quality, target oxide scale structure of free pretreatment container steel has been determined. Trial process was carried out, and test results showed that the oxide scale achieved the desired objects, oxide scale with outer thin Fe₃O₄ layer and inner eutectoid α-Fe+Fe₃O₄. Salt spray test, second adhesion test, and modeling performance basically corroborated the container feasibility.

1. Preface

The container reduces the cost of transporting goods, and attains the goods transport standard. It has the advantages of being safe, rapid, especially suitable for the transportation of high added value, and easy crashing goods [1, 2]. Based on the container transportation, a logistics system of ships, ports, routes, roads, bridges, tunnels, transfer station, multimodal intermodal matching in the world is gradually established, and the world economy has changed as a result [3]. Cu, P, Cr, Ni and other alloy elements are added into the weathering steel for container to make them have good corrosion resistance in the atmosphere. Because of the bad service environment, the requirements of the container surface are very strong corrosion resistance, it requires not only the elements in the matrix of weathering steel to improve corrosion resistance, but also through the container coating system it can further improve the corrosion resistance of coating. Because of surface coating of the container, the outside water and oxygen, electrolyte is separated from steel box, which can stop and retard the corrosion of steel structure box, prolong the service life of the container. The container often uses 3 layers coating system for external and commonly used 2 layer coating system for inner. The quality of surface treatment before application of the coating is the greatest impact of coating life (i.e. antiseptic effect), moreover, it is the main factor affecting coating performance [4, 5].

The traditional coating methods of containers are shot blasting pretreatment before coating, and its main purpose is to remove impurities such as oxide scale, rust and other impurities on the strip surface, and provide the roughness that is favorable to protect performance of the coating. However, shot blasting pretreatment will lead to greater dust pollution in the process of production, and the noise is greater, seriously worsening the operating environment, also shot blasting pretreatment will increase the process cost. The development of container steel without pretreatment can be eliminated shot blasting pretreatment. It can be coated directly on the oxide scale layer. The two coating methods are...
shown in figure 1.

![Diagram of coating layers](image)

**Figure 1.** Comparison of traditional and free shot blasting coating methods of containers. (a) Traditional coating method and (b) Free blasting coating method.

2. Requirements on surface oxide scale of pretreatment container steel

Controlling surface oxide scale structure and the thickness of hot rolling strip, it can be deformed with matrix in the deep processing process without spalling, and the pickling process is canceled, which has been successfully applied to the free pickling automobile beam steel production [6,7]. The container field mainly focuses on the coating technology and coating researching, but the adjustment and improvement of the oxide scale technology for container free blasting pretreatment is not the scope of related studies and reports.

Because of the corrosion, container coating strictly requires on the surface quality. Making the container steel directly coating without blasting pretreatment, it needs oxide scale layer which is compact and clean, the surface roughness is good to the coating, and the oxide scale is good compatibility with the coating system, so it does not affect the performance of coating. At the same time, in the production of container, the steel surface oxide scale needs to adapt to the roller, pressing, cutting, welding and other processes, there is no massive spalling that affects subsequent coating. Different oxide scale structures are of different properties, and the mechanical properties of various types of oxide scale are shown in table 1.

| Oxide scale phase | Tensile strength /MPa | The integrity of oxide scales |
|-------------------|-----------------------|-----------------------------|
| Fe₂O₃             | 10                    | Poor                        |
| Fe₃O₄             | 40                    | Medium                      |
| FeO               | 0.4                   | Poor                        |
| α-Fe+Fe₃O₄        | >40                   | Good                        |

As can be seen from table 1, Fe₂O₃ and eutectoid α-Fe+Fe₃O₄ are higher tensile strength relative to Fe₃O₄ and FeO, and they can bear a certain deformation [8, 9]. In addition, it was reported that the corrosion rate and corrosion oxide scale are different with different structures [10]. The larger the eutectoid reacts, the more the eutectoid structure is, the greater the corrosion’s weight is, and the faster the corrosion rate occurs. Eutectoid structure is a lamellar structure composed of α-Fe and Fe₃O₄. The inhomogeneous microstructure will lead to the formation of micro batteries, making electrochemical corrosion. The whole lamellar Fe₃O₄ or FeO single phase structure has a certain physical shielding effect, so it is relatively better corrosion resistance. Therefore, considering the oxide scale integrity and corrosion resistance, the following scale structure is better comprehensive properties, outer thin Fe₃O₄ layer, inner completely eutectoid structure, as shown in figure 2.

Steel surface after shot blasting treatment can form a wave crest. Through the micro roughness, it is better combination with the coating, ensuring corrosion resistance and adhesion. While free shot blasting pretreatment, with controlling the thickness and structure of oxide scale, the roughness of oxide scale should be controlled so as to improve the quality of the coating.
In addition, for free shot blasting pretreatment container steel, there are still many problems to be solved in container industrial application, such as anti-corrosion in the transportation and storage process of steel, oxide scale protection in the process, etc. [11,12].

3. Production and application of free pretreatment container steel

3.1. Industrial trial manufacture and production process

The chemical composition of the steel for free pretreatment containers is shown in table 2.

| Element | C   | Si    | Mn   | P   | S     | Cu     | Ni   | Cr     |
|---------|-----|-------|------|-----|-------|--------|------|--------|
| Range   | 0.05~0.20 | 0.20~0.50 | 0.30~0.60 | 0.08~0.12 | ≤0.015 | 0.20~0.50 | 0.05~0.40 | 0.30~0.50 |

The surface of the working roll of the end frame of the hot finishing mill is treatment with shot blasting as shown in figure 3. There is a certain roughness on the surface of working roll, and increasing rolling reduction rate, it will be transferred to the strip surface roughness because of the roll surface. It can lift the surface roughness of steel container, which can make up for the surface roughness of shot blasting processing canceled. The method can increase the strip surface roughness Rz from about 6 μm to 20 μm, and help improve the quality of coating.

Discharging temperature of slabs is 1180~1200℃, the final finishing rolling temperature is 860~880℃, interstand water is used in F1-F3 frame work, coiling temperature is 560~590℃, the preceding rapid cooling is used, and wind cooling + packing cooling are controlled between 570~300℃ after coiling, it can reduce the total consumption of Fe₃O₄ under high temperature with long time, and it can be a thin layer of Fe₃O₄ layer, and there is enough α-Fe+ Fe₃O₄ eutectoid structure.

3.2. Oxide scale characters

When the steel coil is cooled to room temperature, samples are carried out when the steel coil is temper rolling. Samples are prepared along the width of the sheet, 30 mm of the edge, 1/4 of the sheet
width, and the center of the sheet width. The morphology, structure and thickness of the oxide scales are observed and analyzed by electron probe. The structure and thickness of oxide scale in each part are shown in figure 4. From the scanning results of the oxide scale, the thickness of the oxide scale is thinner, the thinnest is 4.4 μm, and the thickest is 8 μm. The thinner oxide sheet can guarantee better integrity and adhesion. The oxide scale structure is composed of surface layer Fe₃O₄ and bottom eutectoid Fe/Fe₃O₄, and the surface layer without eutectoid layer can reduce the electrochemical corrosion caused by eutectoid structure.

![Figure 4](image.png)

**Figure 4.** Oxide scale morphology and structure of free pretreatment container steel along sheet width. (a) Side of steel sheet, (b) 1/4 of steel sheet width and (c) 1/2 of steel sheet width.

![Figure 5](image.png)

**Figure 5.** Cold bending surface of free pretreatment container steel. (a) Sample at broadside and (b) Sample at 1/2 width.
3.3. **Examination of adhesion for oxide scale**

The adhesion of oxide scale is tested by 90° cold bending test, the sample specification is 100 ×150 mm, and cold bending core diameter is d=5 mm. According to the cold bending results, there is no massive spalling of oxide scale on the sheet surface during deformation, and the integrity of oxide scale is good, as is shown in figure 5.

3.4. **Performance test after coating**

3.4.1. **Salt spray test.** According to the standard of ASTM B117-2011, salt spray test results are shown in figure 6, the test results show that after 1000 hours salt spray test, inner and external coating samples are qualified with corrosion resistance, but slight difference in second adhesion, mainly in the coating spalling after 1000 h salt spray test.

![Figure 6. Salt spray test. (a) External coating sample and (b) Inner coating sample.](image)

3.4.2. **Molding performance.** During the stamping and roller process of the free pretreatment container steel, the free shot blasting steel sheet also exhibits good formability and adhesion to oxide scale, as shown in figure 7.

![Figure 7. Forming of free pretreatment container steel. (a) Roller forming and (b) Stamping forming.](image)

4. **Conclusions**

The free shot blasting pretreatment container steel has the advantages of traditional container steel in economic and environmental protection, and has great prospects for development. The test results show that the structure of oxide scale is composed of surface layer Fe₃O₄ and bottom eutectoid α-Fe/Fe₃O₄ layer, and the structure control of oxide scale basically achieves the expected goal. Oxide scale integrity and adhesion is good after coating, basically satisfies the container industry needs, but there is some corresponding improvement to do in the future work.
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