Study on The Process Control of DCO3 Low Carbon Aluminum Killed Steel

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Abstract. It is to reduce the performance variation of DCO3 aluminum killed steel be fluctuations caused by components that the smelting and rolling process was controlled and adopted a chemical composition design plan of low-carbon + micro-alloying elements. Research result shows that microstructure of the DCO3 aluminum killed steel plate is ferrite, Further more various mechanical properties of the steel plate are in correspondence with standard requirements.

Keywords: DCO3, aluminum killed steel, smelting, rolling.

1. Introduction
In the production process, the control of alloy composition has a direct impact on the properties of steel [1-4]. The mechanical properties and smelting process of aluminum killed steel DCO3 are affected by carbon content and microalloying elements. When the C content is high, in the smelting process the composition of C is difficult to control, resulting in large fluctuations in carbon content, resulting in high DCO3 strength and poor plasticity, which is not conducive to stamping and forming, resulting in unstable customer performance. In addition, in order to improve the mechanical properties of DCO3, the design idea of adding trace element B is adopted. On the one hand, the control of trace B content increases the difficulty of steelmaking, and also increases the cost of the addition.

To this end, this study uses the "low carbon + aluminum microalloy element chemical composition design plan", through strict control of DCO3 steel smelting and rolling process parameters to solve the problem of large performance fluctuations in production. Provide important process parameters for the development of new products.

2. Production process and related technical parameters
Hot metal-converter smelting-refining-continuous casting-billet heating-rough rolling-finishing rolling-laminar cooling-coiling into the warehouse.
3. Experimental results and analysis

3.1. Process control during smelting

The micro-carbon aluminum killed steel DCO3 is designed with a low-carbon + aluminum composition. Studies have shown that the yield strength and elongation of aluminum killed steel change inversely with the change of carbon content. When the carbon content of aluminum killed steel is 0.015-0.055%, as the carbon content review elongation decreases, the yield strength shows an upward trend; but when the carbon content is 0-0.01%, the elongation rate shows a lower parabolic distribution; When the content is about 0.005%, the elongation reaches the lowest value, and the yield strength shows a parabolic distribution; the carbon content reaches the highest value when it is about 0.007%. This phenomenon is caused by the increase in solid solution carbon. The precipitation of the solid solution carbon obtained by overaging is insufficient and a large amount of solid solution carbon remains in the steel sheet, resulting in an increase in the aging of the steel and deterioration of pressability. The chemical composition (mass fraction, %) of the trial-produced micro-carbon aluminum killed steel DCO3 is shown in Table 1.

| Table 1. DCO3 internal control chemical composition/% |
|------------------------------------------------------|
| C | Si | Mn | P | S | Als | N |
|---|---|---|---|---|----|---|
| Original ingredient standard | 0.015-0.055 | ≤0.03 | 0.15-0.25 | ≤0.025 | ≤0.01 | 0.02-0.05 | ≤0.005 |
| Judgement standard | 0.01-0.02 | ≤0.01 | 0.12-0.18 | ≤0.012 | ≤0.01 | 0.030-0.050 | ≤0.004 |

The lower C content makes the carbide precipitated during the continuous retreat decrease, and the temperature of Ar1 and Ar3 rises. Lower Si content can significantly reduce the yield and tensile strength of the steel and improve the toughness of the steel. A reasonable Als content is conducive to fixing the steel N, forming AlN to reduce the solid solution strengthening effect of N and improve the toughness of the steel. The N content in the steel is one of the main factors affecting the toughness of the steel plate. The acid-soluble aluminum will combine with N to precipitate during the annealing process to form AlN, which can reduce the N content in the steel and improve the toughness of the steel plate. Structure to improve deep drawability. However, the AlN content should not be excessive. AlN precipitated on the grain boundary is the source of microcracks, which is harmful to elongation and damages the toughness of the steel plate. The N content should be further reduced to reduce the amount of AlN precipitation in the steel and improve the coil toughness. Through strict control of the various processes in the smelting process, the element content of the DCO3 steel developed in accordance with the standard requirements.

3.2. Rolling process control

During the steel rolling process, controlled rolling and cooling processes were adopted. The mechanical properties such as yield strength, tensile strength and elongation of DCO3 steel plate are shown in Table 3. Compared with the standard requirements, it is found that the actual elongation of the DCO3 steel plate is higher than the standard performance, the yield strength and tensile strength are in the middle of the standard requirements, and their properties meet the standard requirements. The metallographic structure is a typical ferrite structure as shown in Figure 2.

(1) Hot rolling process

The heating and final rolling in the DCO3 hot rolling process are the same as the traditional aluminum killed steel. The high temperature heating is beneficial to hot rolled flatness control and rolling control. The heating temperature is set to 1523 ± 20 K. High temperature final rolling, the final rolling temperature is set to 1123 ± 20 K, to ensure rolling in austenite zone.

High DCO3 hot rolled cooling temperature: 983 ± 17 K. During coiling at high temperature, the carbides are coarse, which at the same time makes the ferrite matrix purer. In the subsequent annealing, the recrystallization of the ferrite occurs before the solid solution of the carbide (directional nucleation
theory), which is easy to form a strong \{111\} Texture. The purpose of high temperature coiling is to improve the deep drawing performance and promote the softening of the steel plate by controlling the recrystallization texture, and to obtain grain growth under the conditions of rapid heating and short time annealing. The high temperature coiling can make the AIN and cementite of the material more fully analyzed, aggregated and coarse during the hot rolling stage, and promote the formation of uniform ferrite grains. The sufficient analysis of carbon, nitrogen, aluminum and other elements makes the grains purer, which lays the foundation for the effective growth of the grains in the subsequent continuous annealing.

(2) Cold rolling process
The higher the cold rolling reduction, the greater the recrystallization driving force, and the higher the corresponding plastic strain ratio \( r \) value. Figure 1 shows the relationship between the carbon content and the cold rolling reduction rate. When the carbon content is in the range of 0.01-0.02\% and the cold rolling reduction rate is 80-90\%, the \( r \) value is the best. Considering the actual production on site and most customers use thickness \( \leq 1.3 \) mm for stamping and forming of more complex parts, it is generally set in the range of 75-77\%. For thickness \( > 1.3 \) mm, the thickness of hot-rolled raw materials is usually 5.2mm.

| Carbon Content (%) | Cold Rolling Reduction Rate % |
|--------------------|------------------------------|
| 0.001% C           | 80-90                         |
| 0.02% C            | 80-90                         |
| 0.09% C            | 80-90                         |

Figure 1. Effect of C content and cold rolling reduction rate on \( r \) value

(3) Annealing process
The annealing process uses a continuous annealing process. The process execution plan is shown in Table 2. After annealing, the structure is a ferrite structure. As shown in FIG. 2, the recrystallization is sufficient, and the grain size and precipitated carbide levels are normal.

| Process       | Soaking temperature | Slow Cooling | Quick Cooling | Aging   |
|---------------|---------------------|--------------|---------------|---------|
| Annealing     | 820±10              | 670±10       | 450±10        | 350±10  |
According to statistics of the actual production of micro-carbon aluminum killed steel DCO3, the average yield strength, tensile strength and elongation of DCO3 are 178 MPa, 308 MPa, and 44%, respectively, and the process capacity PPK is 1.29, 2.25, 1.34, and the process capacity is good. Yield strength fluctuations become significantly smaller, which is more conducive to customer stamping.

### Table 3 Mechanical Properties of DCO3

|                  | Yield strength | Tensile strength | Elongation |
|------------------|----------------|------------------|------------|
|                  | Mean | Process capability | Mean | Process capability | Mean | Process capability |
| Claim            | ≤210 | ≥1                | 270-370 | ≥1                | ≥34  | ≥1                |
| Actual control   | 178  | 1.29              | 308     | 2.25              | 44   | 1.34              |

### 4. Conclusions

The structure of the DCO3 steel plate produced by the low carbon + aluminum microalloy element chemical composition design scheme is a ferrite structure, the actual elongation is higher than the standard, the tensile strength and yield strength are in the middle of the standard requirements, and their performance meets standard requirement.

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