

# The Precipitation Rule of AlN and Effect on Properties of Wide and Heavy Steel Plate

Lv yanchun, Wang haibao, Liu yang, Zhao xinyu

Technical Research Institute of Shougang Group Co., Ltd.

**Abstract:** The content of different Al elements in the wide thick plate of common carbon steel produces with the different AlN precipitation effect. The precipitation of different sizes and densities has an effect on the properties of steel plate. This study uses small furnace to smelt steel and rolling, through transmission electron microscope to observe the precipitation rule of AlN and the properties of steel plate, with the Al content from 0.030% to 0.070%, the lower Al content of the steel plate is higher than the Al content steel's mechanical properties.

## 1. Introduction

Aluminum steel is a common type steel [1-3], and the content of Al element in aluminum containing steel is generally between 0.010%-0.060%. As the content of steel and nitrogen is generally around 0.0030%-0.0040%, the steel will have AlN with different quantity and size. AlN in steel is a special nitrogen compound that does not belong to the gap phase. The existence of this kind of steel in steel will affect the properties of steel, in order to study the high content of steel. It is necessary for us to do some research on the effect of low AlN precipitation and the performance of steel plate[4-5]. The dissolution and precipitation process of the second phase in the iron matrix is a reversible chemical reaction process. After a long time heat preservation, the amount of elements involved in the solid solution state of the iron matrix and the amount in the second phase in the second phase will be balanced. Changing the chemical composition or temperature of steel, the amount of equilibrium solution and the second phase will also change, resulting in the dissolution and precipitation of secondary phase. Accurately grasping the equilibrium solid solubility of the second phase in the steel matrix, it is possible to quantitatively calculate and design the volume fraction of the second phase in the steel to meet the corresponding needs.

## 2. Test method

The 5 furnace is smelted in small furnace. In order to study the effect of different Al content on steel plate, the content of Al element in steel is controlled at 0.002%, 0.018%, 0.045%, 0.053% and 0.075%, respectively.

Table 1 smelting components in small furnace

	C	Si	Mn	P	S	Als	Alt	[O]	[N]
1	0.18	0.17	0.5	0.007	0.004	0.002	0.004	0.0029	0.0028
2	0.17	0.21	0.52	0.007	0.004	0.018	0.02	0.0034	0.0030
3	0.18	0.17	0.50	0.007	0.004	0.045	0.047	0.0031	0.0038



4	0.19	0.20	0.52	0.007	0.004	0.053	0.055	0.0028	0.0036
5	0.18	0.20	0.51	0.007	0.004	0.074	0.076	0.0029	0.0037

### 3. Data analysis

#### 3.1 Precipitation morphology of aluminum nitride with different aluminum content

##### 1) The content of Al is about 0.004%:

No precipitates of AlN were found in Figure. 1 , the black point is sulfides, and no other abnormal substances were found.

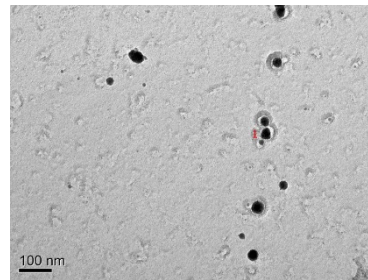


Figure 1 the content of Al is about 0.004%

##### 2) The content of Al is about 0.020%:

In the steel, a very small amount of AlN precipitates are dispersed. As shown below, these precipitates are further observed within 10nm.

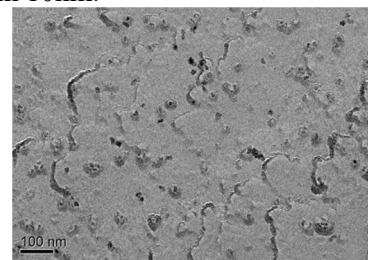


Figure 2 the content of Al is about 0.020%

##### 3) The content of Al is about 0.040%:

As shown below, a large number of large AlN precipitates have been found in steel, with larger particles, more than 50nm in diameter, and a black colored circular sulfide.

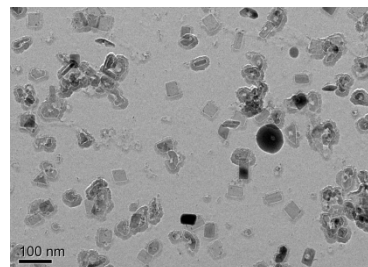


Figure 3 the content of Al is about 0.040%

##### 4) The content of Al is about 0.050%:

As shown below, a lot of dispersed AlN precipitates were found in steel, and the diameters of particles were between 10~50nm.

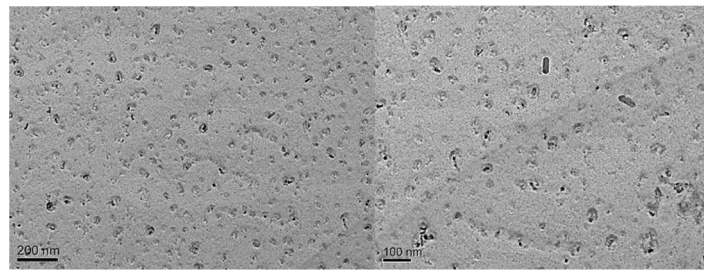


Figure 4 the content of Al is about 0.050%

5) The content of Al is about 0.070%:

As shown below, when the content of Al in steel is about 0.070%, the AlN precipitates in steel become dispersive and distributed, and the diameter of particles is about 20~30nm.

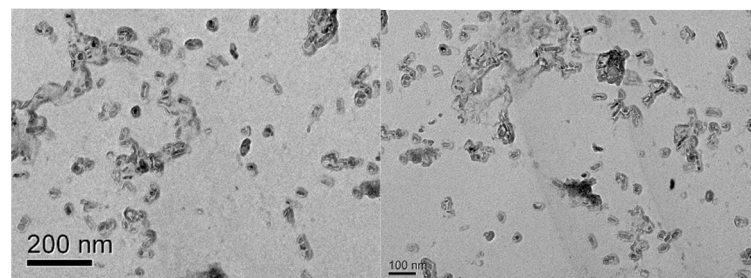


Figure 5 the content of Al is about 0.070%

As shown above, with the increase of Al content in steel, the number of AlN increases gradually. When the content of Al in steel increases to 0.020%, it begins to find AlN in steel. When the amount of AlN increases to about 0.040%, there are large number of AlN precipitates. With the increase of the amount of Al content in the steel, the AlN in steel appears in the state of dense distribution in the steel, and the amount is very large.

### 3.2 Test and analysis

Heating the sample 3, 4, 5 to 1150 degrees, heat preservation 1.0h, uniform heating, rolling the finished product 20mm thick steel plate.

Table 2 mechanical properties of steel plate after rolling

Sample number	Specifications	ReL	Rp0.2	Ts MPa	A%
1	20	319	325	469	37.5
2	20	293	298	438	27.0
3	20	298	308	449	27.5

It is shown in Table 2 that the strength and toughness of 1# specimens are the best, tensile strength is 469MPa, lower yield strength is 319MPa, Rp0.2 is 325MPa, and the elongation at post break is 37.5%. The strength and elongation of 2# and 3# specimens are inferior to 1# samples.

Table 3 lateral impact performance /KV2

Sample number	Notch type	Sample size ( mm×mm)	Test temperature and impact performance /J
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			0°C			-20°C		
1	V	10×10	137	147	148	131	194	81
2	V	10×10	167	152	143	91	101	131
3	V	10×10	158	152	185	87	77	100

It can be seen from table 3 that the three composition systems of 0 °C impact properties are above 100J, and the numerical uniformity is good, the impact of -20 °C, the best of 1# sample, the average value of 150J, the worst impact of 3#, and the average value of about 90J.

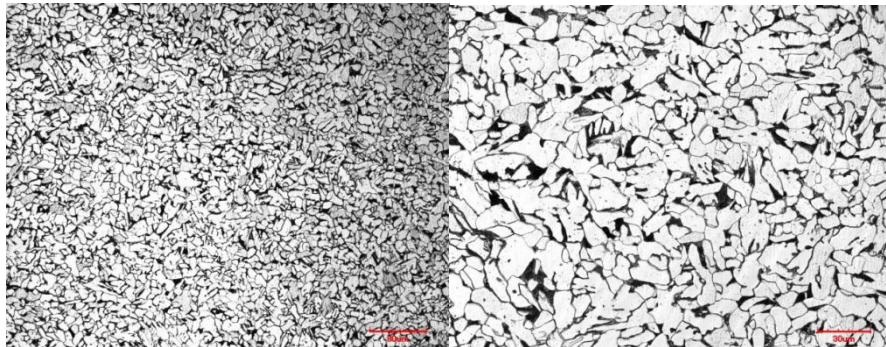


Figure 6 microstructure of 1# component specimen

From Fig. 6, we can see that the microstructure of 1# is mainly ferrite, which contains a small amount of pearlite structure. From the mechanical properties, the elongation of the tissue is excellent, up to 37.5%.

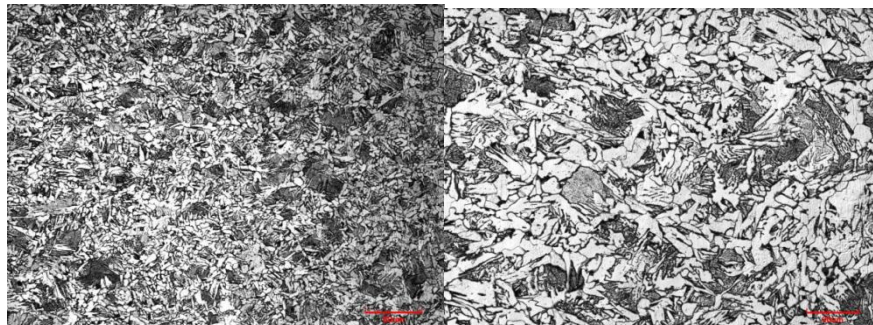


Figure 7 microstructure of 2# component specimen

It is seen in Figure 7 that the tissue is composed of ferrite and bainite, and the ferrite is acicular morphology and grows in a certain direction, so it is close to the Wechsler tissue, and the tissue is hard to extend.

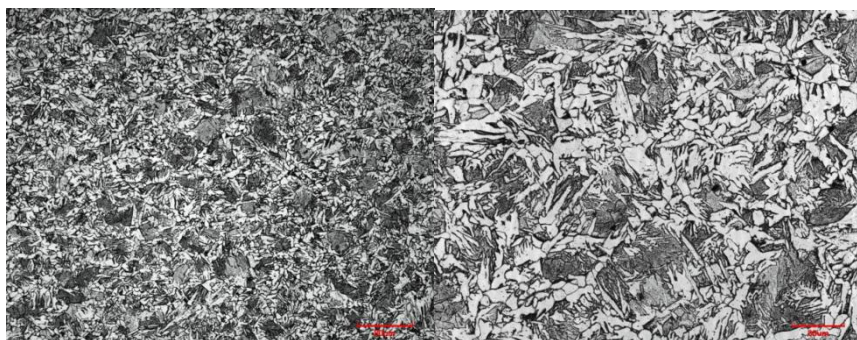


Figure 8 microstructure of 3# component specimen

It can be seen from Fig. 8 that the microstructure is composed of ferrite and bainite, and the bainitic structure is much more than that of 2#. Ferrite is needle like morphology and grows in a certain direction, so it is closer to wustite structure. This kind of tissue has poor extensibility.

#### 4. Research conclusions

1) The mechanical properties and microstructure analysis of the three kinds of steel system steel after the same controlled rolling and controlled cooling process show that the mechanical properties of the 0.047% steel ingot with Al content are better than the Al content of 0.055% and 0.076% ingot, the tensile strength and yield strength are about 20MPa, the difference of impact properties at 0 degrees is not great, the Al content of the impact performance at -20 C is 0.047% better than that of the Al content of 0.055% and 0.076% ingot.

2) After the Al content is 0.047% steel plate rolling, the tissue is ferrite and pearlite, the ferrite structure is about 95%, the Al content is 0.055% and 0.076% steel structure is ferrite and bainite, and the ferrite structure is acicular shape, the growth direction is more obvious, it is similar to the form of Wei's tissue.

3) Analysis indicates that in order to improve the uniformity, strength and impact toughness of steel plate, Al content should be controlled at a low level.

#### Reference

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