

# Industrial development of wide and thick plate X65 pipeline steel

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**Abstract.** The 20.62mm thick X65 trial was carried out on the production line of wide and thick plate. The microstructures, inclusions and mechanical properties were studied by scanning electron microscopy and optical microscopy, low magnification and impact were shown that: (1) The wide plate X65 slab center area is severe and the degree to C level.(2) Inclusions in the finished product is mainly alumina oxide, silicate and composite inclusions, large-scale abnormal non-metallic inclusions were not found.(3)After the first rolling with the microstructure is relatively uniform and small acicular ferrite, grain size acts as 12 grades while the thickness has the center of a slight negative segregation zone, the mechanical properties are to meet the standard requirements but less margin.(4)After adjustment about the second time on the Mn, V composition and rolling process ,Compared with the first batch of steel, the yield strength is more than 20 MPa, which fully meets the requirements of X65.

## 1.Introduction

At present,with the rapid development of the national economy, the demand for petroleum and natural gas has risen sharply,the demand for pipeline steel has increased[1]. With the development of metallurgical design, smelting level and rolling process, pipeline steels with different characteristics and suitable for many conditions are gradually starting to be produced and applied[2].In this paper, the results of steel smelting and rolling process of X65 pipeline steel are researched and analyzed.

## 2.Design of smelting and rolling process.

### 2.1 Chemical composition design

The chemical composition of X65 in the test broad plate is revealed in table 1. The composition design meets the pipeline steel standard and production requirements.

Table 1 Compositions of molten steel (wt%)

| Element | C     | Si   | Mn   | P     | S     | Cr   | V     | Nb   | Al   | Ti    |
|---------|-------|------|------|-------|-------|------|-------|------|------|-------|
| 1       | 0.075 | 0.15 | 1.40 | 0.010 | 0.001 | 0.15 | 0.025 | 0.04 | 0.03 | 0.010 |

### 2.2 Rolling technology design



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The hot rolling process was manifested in table 2, the start rolling temperature was 1140°C, the finishing temperature was 860°C, and the casting billet was rolled to the thickness of 20.62 mm. In order to study the impact of different final cooling temperature on the properties of finished products, three final cooling temperatures of 530 °C 560 °C and 590 °C were specially set.

Table 2 Heating and controlled rolling and cooling process

| Thickness/m<br>m | Start rolling<br>temperature/<br>°C | Finishing<br>temperature/°C | Final cooling<br>temperature/°C |
|------------------|-------------------------------------|-----------------------------|---------------------------------|
| 20.62            | 1140±20                             | 830~890                     | 590±30                          |

### 3. Analysis

#### 3.1 Slab Macrostructure

Using the cold acid to corrode the casting billet as well as observe its macrostructure, Fig. 1 is the test surface of the casting billet after acid pickling. There are obvious stripe segregation bands in the center of the acid corrosion test surface of the billet, the severity functions as C grade. The central segregation of continuous casting slab macrostructure serves as composed of semi-macro segregation, which is relatively independent and has different sizes. The semi-macro segregation characteristics of different solidification macrostructures are different [3, 4].

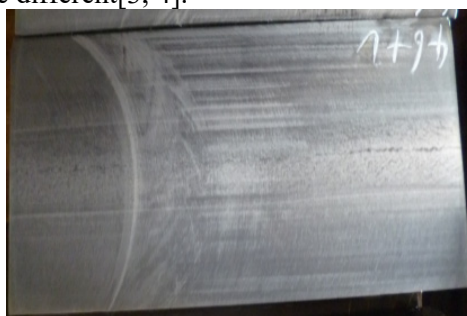


Fig. 1 Casting billet macrostructure

#### 3.2 Research and analysis of inclusions.

The inclusion of finished plate is analyzed by scanning electron microscope (SEM), as illustrated in Fig. 2. The results demonstrate that the inclusions were mainly alumina oxide, silicate and composite inclusions, which were 0.5 grade in shape. The molten steel is pure due to abnormal large non-metallic inclusions are not found.



Fig. 2. Non-metallic inclusions (a) Alumina inclusions ; (b) composite inclusions; (c) Silicate inclusions

#### 3.3 Microstructure

Fig. 3 signifies the surface, 1/4 layer and 1/2 layer microstructure of 20.62mm X65 steel. The microstructure is uniform after rolling, it is fine acicular ferrite, and the grain size is 12 grades. It can

be seen from the picture that the microstructure is uniform after rolling, it is fine acicular ferrite, and the grain size is 12 grades. However, there is a negative segregation band in the 1/2 of thickness. In order to refine the grain size of acicular ferrite and distribute the precipitated phase of microalloyed elements at the grain boundary of ferrite, it is necessary to strictly control the start rolling temperature, finish rolling temperature and cooling rate [5]. The negative segregation zone appears at the corresponding position of casting blank and electromagnetic stirring, presenting a bright white belt. Although the degree of negative segregation in the "bright belt" is lighter than the positive segregation on the center line, it still exists after hot rolling. Trying to avoid the appearance of negative segregation zone [6, 7].

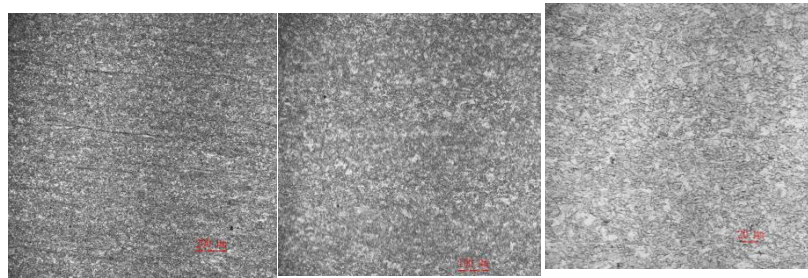


Fig.3 Metallographic microstructure of 20.62mm thick steel plate (a) surface (b) 1/4 thickness (c) 1/2 thickness

### 3.4 Mechanical property

Fig. 4 shows the mechanical properties of 9 steel plates with the thickness of 20.62mm X65. The yield strength of the top and the tail reach 542MPa and 501MPa respectively, and the impact power reaches 360J, which meets the standard requirement.

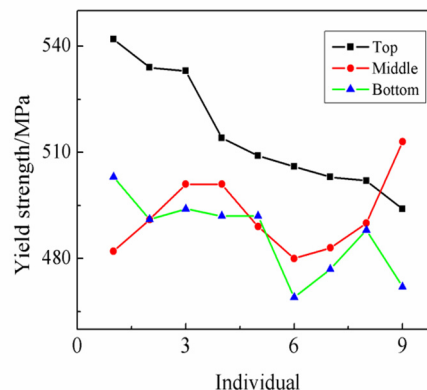


Fig. 4 Yield strength at 20.62mm thickness

### 4. Optimization experiment

Although the mechanical properties meet the standard requirements of the standard, the surplus of yield strength is small, optimizing the composition and rolling process needs to improve the mechanical properties. On the basis of the first experiment, the content of manganese and vanadium were increased by 0.02% and 0.005% respectively. The distribution of rolling pass was adjusted, which stipulated that the pass of rough rolling should not be greater less than 6 passes. In addition, the cooling rate after rolling was increased from 20°C/min to 25°C/min. The experimental results show that the central microstructure of 20.62mm X65 is shown in Fig. 5, and the mechanical properties were

shown in Table 3. The yield strength of the whole steel plate is higher than that of the first batch of steel plates.

Increasing cooling rate after adjustment, the degree of undercooling through the phase transition temperature region is greater, by reducing the transition temperature to enhance the nucleation rate of ferrite and reduce the growth rate of ferrite grain, so the ferrite grain can be refined. At the same time, the greater the cooling rate, the lower the temperature range of pearlite transition, which lead to the smaller control of the morphology size and the precipitation of the microalloy carbonitride[8]. Thus, the improvement of pipeline steel performance is more favorable. The type of microstructure X65 steel plate is ferrite and pearlite, the drop hammer performance will be low when the band-shaped microstructure is severe, the microstructure of the sample surface and the center is a necessary condition for obtaining good drop performance.

Table 3 Uneven zone strength of steel plate top and tail cooling

| Steel plate number | Thickness/mm | Yield strength /MPa | Tensile strength /MPa | Extensibility/% | Yield ratio /% |
|--------------------|--------------|---------------------|-----------------------|-----------------|----------------|
| 1                  | 20.62        | 509                 | 574                   | 40              | 0.89           |

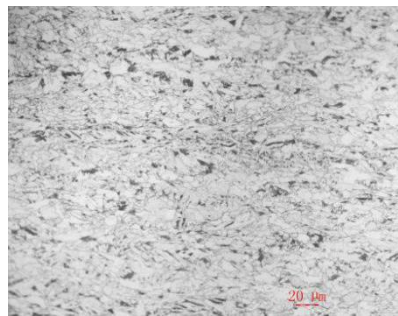


Fig.5 20.62mm thick heart microstructure

## 5. Conclusion

- There is a strip segregation belt in the center area of the slab X65 slab, and the severity is C level.
- The main inclusions in the finished products are alumina oxide, silicate and composite inclusions, and no large abnormal non-metallic inclusions have been found.
- After first rolling for the first time, the microstructure is relatively uniform. It is fine acicular ferrite with a grain size of 12, but there is a slight negative segregation in the center of thickness. The mechanical properties meet the standard requirements, but the surplus is relatively small.
- After the second adjustment of Mn、V composition and rolling process, the yield strength of the steel plate is higher than that of the first batch of steel plates, which fully meets requirements of X65.

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