Effect of Reheating Temperature on Austenite Grain Size and Solid Solution of Second Phase Particles of the Pipeline Steel Slab

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Abstract. Effect of reheating temperature on austenite grain size and solid solution of second phase particles of X70 pipeline steel slab was researched by using optical microscope. The results show that the microstructures are homogeneous and the grain size increases slowly with the reheating temperature increases from 1120°C to 1180°C. However, the abnormal growth phenomenon can be observed in the specimens reheated at 1210°C. The reason is that all second phase particles except TiN, dissolves in austenite at 1210°C. The temperature range from 1140°C to 1180°C is suitable for reheating X70 steel slab.

1. Introduction
Reheating temperature is one of the main control parameters in hot rolling process of the pipeline steel slab. Because reheating temperature affects the austenite grain size and the solid solution amount of alloy elements Nb, Ti and V in austenite [1-4]. When reheating temperature is too high, austenite grains will grow too large to affect the refinement of the grain size; while reheating temperature is too low, the solid solution amount of the alloy elements in austenite is insufficient, which reduces the precipitation effect after hot rolling. Therefore, the reasonable reheating temperature range of the pipeline steel should be taken into account the austenite grain size and the solid solution of alloy elements.

In order to determine the reasonable reheating temperature range, growth behaviour of austenite grains and solid solution rules of second phase particles of X70 pipeline steel slab were researched in this paper.

2. Formatting the title, authors and affiliations
The materials used in this study was X70 pipeline steel slab with chemical composition (mass %): 0.05C, 0.25Si, 1.68Mn, 0.009P, 0.007S, 0.428(Ni+Cr+Cu+Mo), 0.074(Nb+Ti+V) and balance in Fe. The chevron-notch specimens were machined from the pipeline steel slab. The dimensions of the specimens were 20mm×20mm×15mm. The specimens were reheated at the test temperature for 30minutes, followed by cooling in 10 percent salt solution. The test temperature was 1120°C, 1135°C, 1150°C, 1165°C, 1180°C, 1195°C and 1210°C, respectively.
The austenite grain boundary was etched by using saturated picric acid solution + seagull Shampoo + a small amount of hydrochloric acid. The microstructure was observed by using OlympusBX51 type optical microscope. The original austenite grain size was measured by using the transversal method.

3. Result and discussions

3.1. Effect of reheating temperature on size of austenite grain

Figure 1 shows the austenite grain morphology of X70 steel obtained at different reheating temperatures. It is clear that the microstructures are homogeneous when the reheating temperature increases from 1120°C to 1180°C. However, the abnormal growth phenomenon can be observed in the specimens reheated at 1210°C. There are a few austenite grains which are more than ten times larger than their surrounding grains.

![Fig.1 Morphologies of austenitic grains of X70 steel at different reheating temperatures](image)

Fig.1 Morphologies of austenitic grains of X70 steel at different reheating temperatures
(a) 1120°C, (b)1150°C, (c)1165°C, (d)1180°C, (e)1195°C, (f)1210°C
Figure 2 is a curve showing the average grain size of austenite changing with reheating temperature. Generally, the average grain size increases slowly with the reheating temperature increases from 1120°C to 1180°C. Above 1180°C, the average grain size increases quickly. The average grain size at 1210 °C is about two times larger than that at 1180°C.

Figure 3 presents the relationship between reheating temperature and distribution of austenite grain size. When the temperature is 1120-1165°C, the austenite grain with size range of less than 25μm is about 40%. Then, this range of grain decreases quickly with the increase of reheating temperature. Finally, this range of grain is less than 5% at 1210°C.

3.2. Solid solution behavior of alloy elements Nb, Ti and V
During the heating process of X70 pipeline steel, carbonitrides of alloy elements Nb, Ti and V will be dissolved into austenite again. These dissolved elements precipitate more refined carbonitride particles during the subsequent rolling process, and prevent the recrystallization of the deformed austenite.
grains during the rolling process. Therefore, it is necessary to increase the solubility of these elements during reheating.

Alloy carbonitride particles need to reach a certain temperature to completely dissolve in the steel. This temperature is the total solid solution temperature. The total solution temperature $T_{AS}$ can be calculated by Formula (1):

$$ T_{AS} = \frac{B}{A - \log ([M][X])] } $$

(1)

Where $A$ and $B$ are the coefficients of solid solubility product; $[M]$ and $[X]$ are the dissolving amount of alloy elements. The coefficients of solid solubility product for binary compounds in austenite are listed in Table 1[5].

Replace the chemical composition of X70 steel used in this study into Formula (1), and the results are listed in Table 2. It is clear that all second phase particles except TiN, dissolves in austenite at 1210°C. Therefore, the austenite grains can grow quickly. It is the reason why the average grain size at 1210°C is about two times larger than that at 1180°C.

It is noted that the carbide of Nb, V and Ti totally dissolves at more than 1140°C. And the austenite grains are fine at below 1180°C. Thus, the temperature range from 1140°C to 1180°C is suitable for reheating X70 steel slab.

4. Conclusions

(1) The microstructures are homogeneous and the grain size increases slowly with the reheating temperature increases from 1120°C to 1180°C. However, the abnormal growth phenomenon can be observed in the specimens reheated at 1210°C. The reason is that all second phase particles except TiN, dissolves in austenite at 1210°C.

(2) The temperature which ranges from 1140°C to 1180°C is suitable for reheating X70 steel slab.

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