Effect of Heating Temperature on Austenite Grain Size of X80 Steel Slab

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Abstract. Effect of heating temperature on austenite grain size of X80 steel slab was investigated using optical microscope in this study. The results present that the microstructures are homogeneous and the grain size increases slowly with the temperature increasing from 1105°C to 1165°C. However, the abnormal growth phenomenon can be observed in the samples heated at 1195-1210°C. The reason is that all second phase particles except TiN dissolves in austenite at 1195-1210°C. The practical heating temperature range of X80 steel slab is 1110-1165°C.

1. Introduction
Pipeline steels are widely used for the transportation of crude oil or natural gas over a long distance under a high pressure. Therefore, their chemical composition and manufacturing processes must be carefully controlled [1-4]. Heating temperature is one of the key control parameters during thermo-mechanical processes of the pipeline steel slab. Because heating temperature affects the austenite grain size and the solid solution amount of the micro-alloying elements in austenite [4-7]. When heating temperature is too high, austenite grains will grow too large to affect the refinement of the grain size; while heating temperature is too low, the solid solution amount of the micro-alloying elements in austenite is insufficient, which reduces the precipitation effect after thermo-mechanical processes. Thus, the practical heating temperature range should be taken into account both of the austenite grain size and the solid solution of micro-alloying elements.

To determine the practical heating temperature range, growth behaviour of austenite grains and solid solution rules of second phase particles of X80 pipeline steel slab have been investigated in this paper.

2. Formatting the title, authors and affiliations
The experimental material was X80 steel slab with chemical composition (mass %): 0.04C, 0.21Si, 1.64Mn, 0.006P, 0.013S, 0.601(Ni+Cr+Cu+Mo), 0.064(Nb+Ti+V) and balance in Fe. The samples were machined from the pipeline steel slab. The dimensions of the samples were 20mm×20mm×15mm. The samples were heated at the test temperature for 30minutes, followed by cooling in 10 percent salt solution. The test temperature was 1105°C, 1120°C, 1135°C, 1150°C, 1165°C, 1180°C, 1195°C and 1210°C, respectively.
The metallographic samples were etched using saturated picric acid solution + seagull Shampoo + a small amount of hydrochloric acid. The microstructure was observed using OlympusBX51 optical microscope. The austenite grain size was measured using the transversal method.

3. Result and discussions

3.1. Effect of heating temperature on austenite grain size

Figure 1 presents the austenite grain morphology of X80 steel slab obtained at different heating temperatures. It is clear that the microstructures are homogeneous when the heating temperature increases from 1105°C to 1165°C. However, the abnormal growth phenomenon can be observed in the samples heated at 1180-1210°C. There are some austenite grains which are more than ten times larger than their surrounding grains.

Fig.1 Morphologies of austenitic grains of X80 steel slab at different heating temperatures
(a) 1105°C, (b)1150°C, (c)1165°C, (d)1180°C, (e)1195°C, (f)1210°C

Figure 2 is a curve that presents the average grain size of austenite changing with heating temperature. Generally, the average grain size increases slowly with the temperature increasing from
1105°C to 1150°C. However, the austenite grains quickly grow above 1165°C. The average grain size at 1210 °C is more than two times larger than that at 1165°C.

Fig.2 Effect of heating temperature on average grain size of austenite

Figure 3 presents the relationship between heating temperature and distribution of austenite grain size of four ranges. Austenite grains with size range of 25-50μm account for about 50% at 1105-1150°C. And then the austenite grain size quickly increases with heating temperature. Finally, austenite grains larger than 100μm account for about 50% at 1195-1210°C.

3.2. Solid solution behavior of micro-alloying elements

During the heating process of X80 steel slab, carbonitrides of micro-alloying elements Nb, Ti and V will be dissolved into austenite again. These dissolved elements precipitate more refined carbonitride particles and prevent the recrystallization of deformed austenite grains during the subsequent thermo-mechanical processes. Therefore, it is necessary to increase the solubility of these elements during heating.

Alloy carbonitride particles need to reach a certain temperature to completely dissolve in austenite grains. This temperature is generally defined as the total solution temperature. The total solution temperature, T_{AS}, can be calculated by Formula (1):
$$T_{AS} = \frac{B}{A - 1g[M][X]}$$

(1)

where A and B are the coefficients of solid solubility product; [M] and [X] are the dissolving amount of micro-alloying elements. The coefficients of solid solubility product for binary compounds in austenite are shown in Table 1[8].

| Binary compounds | A  | B   |
|------------------|----|-----|
| TiN              | 0.32 | 8000 |
| TiC              | 5.33 | 10475 |
| NbN              | 3.7 | 10800 |
| NbC              | 2.04 | 6500 |
| Nb(C,N)          | 2.26 | 6770 |
| VN               | 3.63 | 8700 |
| VC               | 2.72 | 6080 |

Replace the chemical composition of X80 steel slab used in this study into Formula (1), and then the results are presented in Table 2. It is noted that all second phase particles except TiN dissolves in austenite at 1187°C. Therefore, austenite grains can quickly grow above 1187°C. It is the reason why austenite grains larger than 100μm account for about 50% at 1195-1210°C.

| Binary compounds | Solid solution temperatures /°C |
|------------------|-------------------------------|
| TiN              | 1431                          |
| TiC              | 934                           |
| NbN              | 1187                          |
| NbC              | 1106                          |
| Nb(C,N)          | 1109                          |
| VN               | 692                           |
| VC               | 586                           |

It can be seen that the carbide of Nb, V and Ti totally dissolves at more than 1109°C. And austenite grains are very fine below 1165°C. Thus, the temperature range from 1110°C to 1165°C is suitable for heating X80 steel slab.

4. Conclusions
(1) The microstructures are homogeneous and the grain size increases slowly with the temperature increasing from 1105°C to 1165°C. However, the abnormal growth phenomenon can be observed in the samples heated at 1195-1210°C. The reason is that all second phase particles except TiN dissolves in austenite at 1195-1210°C.

(2) The practical heating temperature range of X80 steel slab is 1110-1165°C.

Acknowledgments
Authors wishing to acknowledge financial support from Henan Natural Science Foundation (No.182300410209).

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