Study on Austenite Grain Growth Behaviour of New Pipeline Steel for Deep Sea

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Abstract. The austenite grain growth behaviour of new pipeline steel for deep sea was researched by using optical microscope. The results show that the microstructures are homogeneous and the grain size increases slowly while the soaking temperature increases from 1120°C to 1180°C. However, the abnormal growth phenomenon can be observed in the specimens reheated at 1210°C. The austenite grain growth behaviour can be described by following equations: lnD = 7.7738 - 6242/T (1120°C≤ T≤ 1180°C) and lnD = 51.2948 - 69510/T (1180°C< T ≤1210°C).

1. Introduction
The pipeline steel for deep sea must have good mechanical properties, such as compressive strength and low temperature toughness. It is usually required that this kind of steel has fine and uniform microstructure. When the soaking temperature of casting slab is too high, austenite grains will grow too large to affect the refinement of the final microstructure. Therefore, austenite grain growth behaviour should be examined before the new pipeline steel is put into production.

A lot of papers reported that soaking temperature, time and second phase particles can significantly affect the growth behavior of austenite grains [1-3]. In this paper, the austenite grain growth model of the new pipeline steel is obtained by mathematical fitting calculation, which provides the basis for the actual production.

2. Experimental Procedure
The materials used in this study was the new pipeline steel slab with chemical composition (mass %): 0.06C, 0.27Si, 1.66Mn, 0.010P, 0.007S, 0.431(Ni+Cr+Cu+Mo), 0.075(Nb+Ti+V) and balance in Fe. The specimens were machined from the steel slab. The dimensions of the specimens were 20mm×20mm×15mm. These specimens were heated at the soaking temperature for 1 hour, followed by cooling in 10 percent salt solution. The soaking 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 Olympus BX51 optical microscope. The original austenite grain size was measured by using the transversal method. The number of austenite grains measured was more than 300.
3. Result and Discussions

3.1. Effect of Soaking Temperature on Size of Austenite Grain

Figure 1 presents the austenite grain morphology at different soaking temperatures. It is clear that the grain size increases slowly when the soaking temperature is between 1120°C and 1180°C. However, the grain size increases quickly when the soaking temperature is higher than 1195°C. The abnormal growth phenomenon can be observed at 1210°C as shown in Figure 1 (g).

![Figure 1](image)

**Figure 1.** Morphologies of austenitic grains of the specimens at different soaking temperatures (a) 1120°C, (c) 1150°C, (d) 1165°C, (e) 1180°C, (f) 1195°C, (g) 1210°C

Figure 2 shows the distributions of austenite grain size of the specimens in Figure 1. When the soaking temperature range is 1120-1165°C, the distribution peak of austenite grain size is 15-25μm. And the maximum of austenite grain size is less than 100μm. As shown in Figure 2(f), two distribution peaks of austenite grain size appear in the specimens at 1195°C. One peak is 20-25μm, another is 40-45μm. The maximum of austenite grain size is about 220μm. Only one distribution peak of austenite
The grain size is 45-55 μm in the specimens at 1210°C. However, the maximum of austenite grain size is about 350 μm, which is more than 7 times larger than the peak value.

Figure 2. Distribution of austenite grain size of the specimens at different soaking temperatures (a) 1120°C, (c) 1150°C, (d) 1165°C, (e) 1180°C, (f) 1195°C, (g) 1210°C

Figure 3 shows the effect of soaking temperature on average grain size of austenite. Generally, the average grain size increases slowly with the soaking 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. Effect of soaking temperature on average grain size of austenite

3.2. The Model of Austenite Grain Growth Behaviors
At present, most scholars usually adopt a model to describe austenite grain behaviours as shown in Equation (1):

\[ D^2 = D_0^2 + A \exp\left[-\frac{Q}{RT}\right] \cdot t \]  

where, D is the average grain size after time t, μm; D_0 is the initial average grain size, μm; t is the soaking time, s; T is the absolute temperature, K; R is the gas constant, 8.31 J/(mol•K); Q is the activation energy of grain growth, and A is a constant for the tested steel [5].

In this study, soaking time \( t = 3600 \text{s} \) replaces in Equation (1):

\[ D^2 = D_0^2 + B \exp\left[-\frac{Q}{RT}\right] \]  

where, B is the new constant for the tested steel. From Equation (2), the relation of \( \ln D \) with \( 1/T \) should satisfy linear relation.

Figure 4 shows the relationship of soaking temperature and average grain size of austenite. It is clear that there are two fitting lines in Figure 4. The activation energy Q can be obtained by calculating the slope of fitting lines. Then, Equation (2) can be written as follow:

\[ \begin{align*}
\ln D &= 7.7738 - 6242/T & (1120°C \leq T \leq 1180°C) \\
\ln D &= 51.2948 - 69510/T & (1180°C < T \leq 1210°C)
\end{align*} \]  

(3)
Figure 4. Relationship of soaking temperature and average grain size of austenite

4. Conclusions
(1) The microstructures are homogeneous and the grain size increases slowly while the soaking temperature increases from 1120°C to 1180°C. However, the abnormal growth phenomenon can be observed in the specimens reheated at 1210°C.

(2) The austenite grain growth behaviour can be described by following equations: \( \ln D = 7.7738 - 6242/T \) (1120°C ≤ T ≤ 1180°C) and \( \ln D = 51.2948 - 69510/T \) (1180°C < T ≤ 1210°C).

5. References
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