5 Microstructure Fining Theory of Low-carbon Bainitic Steel

The modern Low (Ultra-low) Carbon Bainitic Steel (ULCB) is a high-strength, high-toughness and multi-application steel. Its appearance is the consequent result of the social need and the development of the modern metallurgy technology in recent 30 years. Due to the sharp reduction of the carbon content in the steel, the disadvantageous effects of the carbon on the toughness of the bainite microstructure is eliminated completely, and the fine bainitic matrix microstructures with a high dislocation density can be obtained with the controlled rolling and controlled cooling. The strength of the steel does not depend on the carbon content in the steel any more, and it is primarily guaranteed by the following methods: fine grain strengthening (microstructures), dislocation and substructure strengthening, the precipitation strengthening due to the micro-alloying elements such as Nb, Ti, and V, as well as the sediment strengthening of the $\varepsilon$-Cu. The strength and the toughness of ULCB steel match perfectly, and especially the steel has excellent field welding performances and the capability of resisting HIC (hydrogen induced cracking). In the end of chapter, a theoretical concept is proposed for the further fining on the basis of the overview of fundamental microstructures and performance characteristics of the new steel. A theoretical concept is proposed for the further fining.

5.1 Social Needs for Low-carbon Bainitic Steel with a Grade of More than 600MPa

In the world, the characteristics for the low-alloy high-strength medium and heavy steel plates with excellent welding performances, are large usage as well as its multi-applications. At present, the steel is largely used in the equipments such as
various engineering machinery, large electric shovels, bulldozers, dump trucks, oil & gas pipelines, drilling platforms, drilling machines and coal synthesized excavating machinery (hydraulic stands, drag conveyors), which are commonly used in many fields such as energy source, traffic, raw material industries and various engineering constructions. The common characteristics of the equipments are that the steel should be required to have a high strength (generally tensile strength of more than 600MPa), a high toughness or a low-temperature toughness (especially for the equipments used in a cold region), good welding performances and a cold formability (generally with a simple welding process required, without treatment before or after welding), a good cold bending (including wide cold bending) property. In addition, the steel should also have a good fatigue resistance and a certain corrosion resistance. To reduce the cost of manufacturing various equipments and improving technological properties, the steel is generally expected to have low carbon and alloying element contents, be adapted for different needs, and have a wide selecting range in the properties and specifications so as to meet the requirements of different customers. For example, in the construction of the oil & gas pipelines, if X80 or X100 steel is selected instead of X52 steel, large amounts of material can be saved because the pipe wall can be thinned sharply, and the pipe pressure is also raised and more energy sources are conveyed. For large members such as bridges, buildings, the weight-reduction requirement of these members can be met. Therefore, the social needs for the steel with a grade of more than 600MPa are increasingly wider and larger.

The primary drives to develop the low-carbon bainitic, high-strength, high-toughness and multi-application steel, are the complete meeting for social needs, reduction in the production and use costs of the high strength and toughness steel, and meeting for technological requirements such as welding. Of course, there are also two key technology factors for the appearance of large batches of commercial low (ultra-low) carbon bainitic steels in the practical industrial mass production in recent years. One is the development of the metallurgical production technology. The first is the large-scale application of the ladle metallurgy technology, which makes it possible to mass-produce the low (ultra-low) carbon steel; thus, in steel making, after the carbon content is decreased sharply, the contents of the gases such as oxygen, nitrogen in the steel are decreased, and the reclamation of various trace elements is controlled. In the hot processing technology, the complete development of TMCP technology, realizes the full-process control of the steel production. The other key technology factor is the complete development of the study and applications on micro-alloying elements such as Nb, Ti, V, B, especially the study and applications on the combined effect of trace Nb and Nb-B, Nb-Cu-B, playing a prominent role in the development process. At present, in the world, there have been a series of low (ultra-low) carbon bainitic steels formed, with the yield strength of more than 600MPa,