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A VIEW FROM THE PENTHOUSE: USEFUL INFORMATION FOR THE WORLD OF BOILERS

BANDED MICROSTRUCTURES

Some plain-carbon steels similar to SA178 or SA210 grades of boiler tubing occasionally have a segregated structure of alternating layers, or bands, of ferrite and pearlite, see Figure 1.

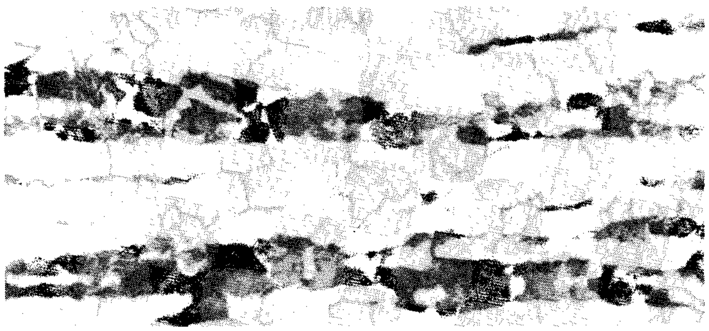

Figure 1. SA210 A-1, 500x

Such structures are called "banded." To understand these structures we begin with an explanation of the formation of ferrite and pearlite.

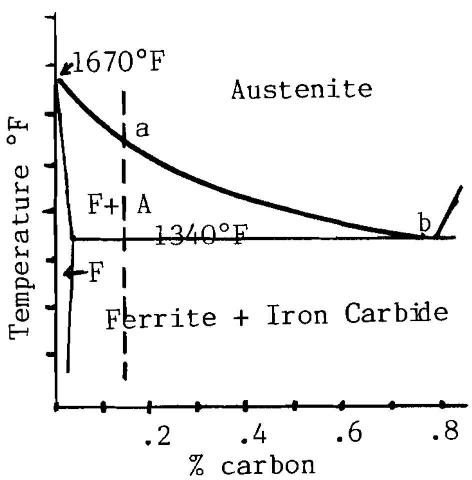

Figure 2.

Figure 2 is a sketch of a portion of the iron/carbon diagram which presents the phases in equilibrium in the temperature range from 1000°-1800°F for carbon contents from 0-approximately 0.8%. While this holds strictly only for iron-carbon alloys, it is generally true for all low-alloy steels. For illustrative purposes, our discussion will be for a 0.15% carbon steel represented by the vertical dashed line. All hot working is done at temperatures above 1800°F where the crystal structure or arrangement of iron atoms is all austenite. Austenite will dissolve up to about 2% carbon within the holes in the austenite lattice, while ferrite will dissolve practically no carbon, only 0.02%. When austenite is slowly cooled from, say, 1800°F, ferrite begins to form at point "a", about 1550°F. Continued cooling increases the amount of ferrite and decreases the amount of austenite. The carbon content of austenite increases until point "b" where the % carbon equals 0.77, and the temperature is 1340°F. The relative amounts of ferrite and austenite differ but the overall % carbon remains 0.15. At 1340°F the 0.77% C austenite transforms to pearlite, a mixture of ferrite and iron carbide, Fe_3C.

At 1340°F relative amounts of austenite and ferrite for 0.15% carbon are approximately 83% by volume ferrite, and 17% by volume of austenite. On further cooling below 1340°F, the austenite transforms to pearlite, the gray patches shown in Fig. 1. Pearlite is made up of alternating layers of iron carbide and ferrite. Mixtures of ferrite and lamellar pearlite are referred to as "normalized structures"; that is, the structures that follow the slow cooling of austenite from temperatures above about 1550°F.

The preceding description has

been of steels of iron and carbon only with no other alloying elements added. In reality, all steels contain at least approximately 0.5% manganese, the actual amount depends on the grade of steel. Lesser amounts of phosphorus, sulfur, and silicon are also present in these plain-carbon steels. Measurable amounts of chromium, nickel, molybdenum, vanadium, copper, are also likely. Segregation of all alloying elements, but mainly manganese, during the casting of the original ingot, alters the diffusion rate of carbon through austenite. The result is regions of higher carbon content in the austenite. Rolling of the ingot and tube forming elongate these regions in the direction of hot work. The effect is to leave the austenite with a non-uniform carbon content.

Thus during the final heat treatment, the non-uniform carbon content of the austenite leads to the banded structure shown in Figure 1. When cooled from 1800°F, the lower carbon regions of austenite transform to ferrite at a higher temperature than the higher carbon regions. Since the hot working has stretched and elongated these regions, the final structure is as presented in Figure 1.

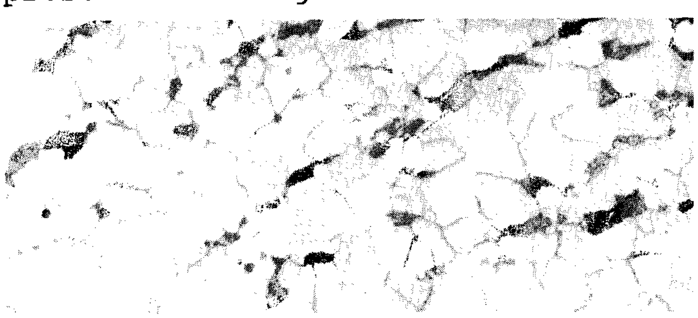

Figure 3. SA210 A-1. 500x

While banded structures are not unusual, and have no adverse effect on the mechanical behavior and mechanical properties of these steels, it can lead to peculiar microstructures as a result of tubing manufacture. In the fabrication of seamless tubing, one of the first steps is to put a hole in a solid billet, usually by a rotary piercing operation. Such a rotary motion on a stationary billet leads to a "twisting" of the microstructure along the ID surface. This twisting motion can take the banded structure of the billet and distort the structure relative to the ID surface, as shown in Fig. 3. The ID surface is parallel to the bottom edge of the photograph.

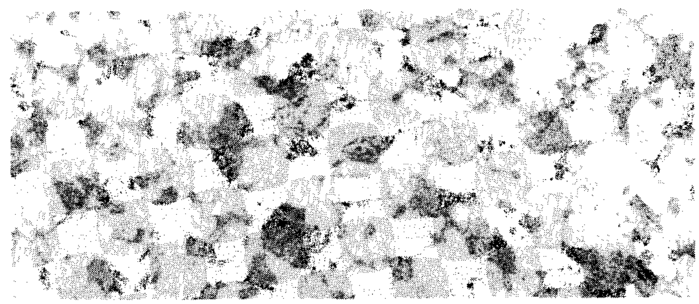

Figure 4. SA213 T-22. 500x

These banded structures are fairly common in the plain-carbon steels, but less obvious in the low-alloy ferritic steels similar to T-11 and T-22. The normalizing heat treatment for these alloys is usually performed at a higher temperature where the diffusional mobility of the alloying elements leads to a more uniform chemical composition and a more uniform dispersion of the pearlite throughout the ferrite, as shown in Fig. 4.

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