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Carbide Morphology in Steel Subjected to Cold Deformation

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Abstract—Spheroidizing annealing is an important step in the manufacture of metal products by cold upsetting. Deformational and thermal treatment ensures high levels of cementite spheroidization with highly uniform product structure and properties.

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Globally, metal products are mainly manufactured from rolled subeutectoidal structural steel by cold plastic deformation—primarily cold upsetting and stamping. As we know, phase recrystallization of austenite to a ferrite–cementite mixture occurs on natural cooling of subeutectoidal steel in air from supercritical temperatures. This leads to pearlite formation, with accompanying ferrite and cementite. The pearlite is of plate form on account of the dominance of the kinetic factor over the energy factor in the transformation of austenite. In these conditions, the formation of plate pearlite is energetically favored over globular pearlite. According to current requirements, however, rolled steel that is to be subjected to cold upsetting or stamping must initially contain a specific pearlite structure—pearlite with globular morphology of the carbide phase, which proves the most economical and easiest to work.

To obtain the required microstructure in the rolled steel, it must be subjected to special heat treatment: spheroidizing annealing. However, since the phase diagram of subeutectoidal steel does not include a carbide region, spheroidization of the cementite present is relatively challenging. Therefore, until recently, such annealing was not employed. In addition, many researchers agree with Gulyaev [1, 2]: "In subeutectoidal steel, granular pearlite offers no benefits over any other structure." This remains true for processes based on turning. Globally, however, such processes represent a negligible fraction of production, and cold upsetting is the primary means of producing bolts, screws, and other metal components. Therefore, Gulyaev's assertion is out of date, for practical purposes. Today, the development of economical means of spheroidizing treatment is a high priority.

Researchers in the department devoted to the heat treatment of metals at Ukrainian National Metallurgical Academy have developed several technologies for carbide spheroidization in steel. After industrial testing, we may recommend these technologies for industrial use. Some of these technologies were described in [3] and elsewhere. Our experience suggests that, in technological and economic terms, the best approach to carbide spheroidization in steel—in particular, subeutectoidal steel—includes two stages: preliminary treatment to hasten the spheroidization of plate carbide or to form carbides of quasi-globular or globular morphology; and subsequent brief spheroidizing annealing, with or without phase recrystallization to ensure coagulation and coalescence of such carbides to the required size and also the attainment of the hardness required by the standard documentation.

This approach is not only faster than traditional spheroidizing annealing but also yields better spheroidization and hence better product quality after final heat treatment.

The preliminary treatment employed will depend on the manufacturing method subsequently employed (rolling, forging, drawing, etc.), the type and standard of the deforming equipment, the presence or absence of controlled cooling between the rolling cells and beyond the final cell, the grade of steel, the shape and cross section of the rolled blank, and the standard requirements on the grain size of the carbide phase and the hardness of the steel.

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