EFFECT OF CARBON, MANGANESE, PLASTIC DEFORMATION, AND HEAT TREATMENT ON THE STRUCTURE AND PROPERTIES OF AUSTENITIC MANGANESE STEEL

V.I. Grigorkin and G.V. Korotushenko

UDC 620.17:620.18:669.15-194.56'174

We investigated three series of melts with constant manganese concentrations (13, 16, and 19%) and varying carbon concentrations (see Table 1). The steel was melted in a vacuum induction furnace from a charge of Armco iron and pure manganese. The ingots weighed 5 kg. Homogenizing annealing was conducted under the following conditions: slow heating (80-100°C/h) and soaking 2 h at 720-750°C, further slow heating and soaking 5 h at 1150-1200°C, cooling in air. After homogenization the ingots were heated to 1180-1200°C and forged into blanks for samples.

After preliminary machining the blanks were austenitized in a salt bath at 1050°C with subsequent cooling in water. A series of blanks for magnetic tests were held, after austenitizing, for 90 h at temperatures of 300-700°C (50°C intervals). The samples were ground to size.

Under certain conditions the \( \alpha \) and \( \varepsilon \) phases can precipitate from high-alloy austenitic manganese steel. It was shown in [1-6] that such transformations are possible in Fe-Mn systems (12-24% Mn) with carbon, chromium, nickel, molybdenum, and cobalt and also in austenitic chromium-nickel steels [7].

In this work we investigated the effect of carbon and manganese and also plastic deformation on the phase composition of the melts, using the method described in [4].

![Fig. 1](image1.png)

**Fig. 1**. Phase composition of manganese steels. a) Solid solution; b) cold worked by stretching \((\delta = 30\%)\). 1) Data from [3]; 2) data from present work; 3) data from [6].

![Fig. 2](image2.png)

**Fig. 2**. Effect of strain (cold working) on the amount of \( \alpha \) phase in melts 6, 8, and 23.

Figure 1 shows the dependence of the phase composition in steels with 13% Mn on the carbon content after austenitizing and after cold plastic deformation in tension (30%). Steel 1 had the following phase composition: 5% α, 18% ε, 77% γ (Fig. 1a). These results are in good agreement with the data from [5, 6], but differ somewhat from other data [3], apparently because of the higher manganese concentration (about 14%). Plastic deformation induces changes in the proportions of the phase (Fig. 1b). After cold working, steel 1 consists of the following phases: 47% α, 21% ε, 32% γ. The maximum development of the γ → ε → α transformation is attained in plastic deformation of the steel with 0.2% C, while at 0.8–0.9% C this transformation is slowed down, which can be considered conditionally as the boundary of the "stability" of austenite. No precipitation of secondary phase was recorded in x-ray structural analysis or by the ballistic method. Therefore, we used a magnetic microbalance [4] to reveal ferromagnetic phases. The amount of α phase in melts 6, 8, and 23 cold worked to 60% austenite was small, amounting to 1.28, 1.0, and 0.38% respectively (Fig. 2), which also indicates the stabilizing influence of carbon on the γ phase.

Figure 3 shows the variation of the mechanical properties with the carbon content of steels with 13, 16, and 19% Mn. The low- and medium-carbon (unstable) manganese steels have a low plasticity (δ reduced five times, ψ reduced three times) and strength by comparison with the "stable" high-carbon steel. For example, for melt 1, containing 0.07% C: 0.2 = 39.1 kg/mm², 0.5 = 146.1 kg/mm², HV = 230, δ = 16.9%, ψ = 18.2%. For melt 9, with 1.1% C: 0.2 = 42.6 kg/mm², 0.5 = 116.2 kg/mm², S = 212.8 kg/mm², HV = 228, δ = 80.4%, ψ = 53.2%. Thus stable austenite is more plastic and stronger.

Like ferritic steels, austenitic manganese steels become brittle at low temperatures (Fig. 4). It was shown in [9] that cold brittleness of austenitic manganese steels is induced by other causes than in ferritic steels. It is caused by the formation of α phase under the influence of plastic deformation in the process of testing itself.

For this reason, the low-carbon melt 1 has a relatively low impact strength (17.5 kgm/cm²) at room temperature and high susceptibility to cold brittleness (Fig. 4). With 0.6% C (melt 4) and 1.1% C...