CAST IRONS

OPTIMIZING THE CARBON AND MANGANESE CONCENTRATIONS IN WEAR-RESISTANT CHROMIUM CAST IRONS

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This work* concerns the combined effect of manganese and carbon on the abrasive (microcutting) and impact-abrasive wear resistance of chromium cast irons.

Chromium cast irons were selected for the investigation because they have high wear resistance under conditions of abrasive wear of the microcutting type [1]. The carbon content of the cast irons was varied from 1.0 to 4.1% and the manganese content from 0.4 to 8.4%, with a constant chromium content (12-14%). The abrasive wear resistance was determined by the Stauffer method [2] with impact-abrasive wear resistance tests in the TsUK-3 centrifugal accelerator. As abrasive we used cast iron shot 0.8-1 mm in diameter; the flight speed of the shot was 60 m/sec, the angle of attack 30, 60, and 90°.

The wear resistance of the cast irons was determined from the coefficient of relative wear resistance K, characterizing the ratio of the volumes of the worn parts of a control sample and the sample tested, and determined by the formula

\[ K = \frac{\Delta V_c}{\Delta V_s} = \frac{\Delta G_{cs}}{\Delta G_{c}} , \]

where \( \Delta V_c, \Delta V_s, \Delta G_s, \rho_c, \) and \( \rho_s \) are the reduction in volume, weight, and density of the control sample and the tested sample, respectively.

Steels 20 and St3 were used as control samples.

Samples were prepared from castings made in green sand molds and quenched to maximal hardness before the tests.

The combined effect of carbon and manganese on the wear resistance of cast irons under microcutting conditions is shown in Fig. 1 (the curves indicate the carbon and manganese concentrations ensuring the same resistance of cast irons). With increasing concentrations of carbon the wear resistance of the cast iron rises due to the larger quantity of carbides, while increasing the manganese content, which stabilizes austenite, leads to a substantial reduction of the wear resistance.

The effect of manganese (with a fixed carbon concentration) on the impact-abrasive wear resistance is shown in Fig. 2, where it can be seen that the relationship is extremal in character. With increasing amounts of manganese the amount of metastable retained austenite rises from 10 to 100%. In the process of wear under the influence of normal impact the metastable austenite is transformed to martensite; the kinetic energy of abrasive particles is partially spent on phase transformation. This weakens the destructive influence of the

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normal component of the impact pulse. The higher the manganese content, the larger the amount of retained austenite and the greater the energy spent on phase transformation, and thus the higher the impact wear resistance of the cast iron. Wear of the microcutting type (due to the tangential component of the impact pulse) does not depend on phase transformation, since microcutting occurs in the most work hardened condition. Thus, raising the manganese content leads to a weaker overall effect of the impact pulse, the impact-abrasive wear resistance of the cast iron increasing. With a completely austenitic structure of the cast iron, which corresponds to the peaks on the curves of impact-abrasive wear resistance vs manganese content (Fig. 2), the stability of austenite increases with the manganese content, while the energy of the normal component of the impact pulse becomes insufficient to induce phase transformation. Thus, the impact-abrasive wear resistance of the cast iron decreases.

With increasing amounts of carbon the quantity of brittle carbide phase increases and the distance between carbide decreases, as the result of which the impact-abrasive wear resistance also decreases (the curves shift downward and become flatter). Increasing the angle of attack from 30° to 90° leads to a lower overall level of impact-abrasive wear resistance and a weaker effect of manganese.

The combined effect of carbon and manganese on the impact-abrasive wear resistance at different angles of attack is shown in Fig. 3. From this diagram one can determine the wear resistance of cast iron, knowing the carbon and manganese concentrations, or solve the reverse problem — select the composition of the alloy with a given resistance. Cast irons containing not over 2.3% C have satisfactory resistance at all angles of attack. It should be noted that the highest resistance of cast iron with an equal carbon concentration at all angles of attack tested is ensured by approximately the same manganese concentration (e.g., 2-4% Mn for cast iron with 2-2.5% C). Higher manganese concentrations lead to lower impact-abrasive wear resistance due to stabilization of austenite. This must be taken into account in selecting the composition of cast iron for operation under impact-abrasive wear conditions. However, the optimal composition for such operating conditions does not always provide the highest abrasive wear resistance. For example, cast irons with 1.7-2.2% C (Fig. 1) should be used for operation under conditions of substantial impact loads. If, however, the angle of attack does not exceed 30° then the carbon content can be raised to 3.25%.

Comparing the impact-abrasive wear diagrams (solid lines in Fig. 3) with similar abrasive wear diagrams (dashed lines in Fig. 3), one can determine the necessary amounts of manganese and carbon to ensure high wear resistance of cast iron under various operating conditions.