In investigation of the structure and strength properties of carburized and carbonitrided 12Kh2N4A steel, a difference in its properties was observed. This is especially significant in determination of impact strength, the values of which differ by several times.

To reveal the reason for this spread in properties an electron microscopic investigation was made of the fracture surface of impact specimens of 12KhN4A steel. The investigation was made on a JSM-35CF scanning electron microscope with magnifications from 900× to 3000×. The impact strength was determined on 10 × 10 × 55 mm specimens without a notch at normal temperature on an MK-30 pendulum impact tester.

The investigation was made on carburized and carbonitrided specimens treated using the cycles in Table 1, which also gives the results of investigation of impact strength and bend resistance.

Figure 1a and b shows the fracture structure of the surface zone of the carburized case. At a distance of 0.01-0.015 mm from the surface, fracture in the grain boundaries is observed (Fig. 1a). Such a character of fracture may be explained by the fact that this zone corresponds to the zone of internal oxidation, where finely dispersed carbides and oxides causing embrittlement of them are located in the grain boundaries [1, 2]. At a greater distance from the surface (Fig. 1b) a mixed character of fracture is observed in the carburized case. Areas of intergranular fracture caused by precipitation of carbide phase at the grain boundaries are encountered on a background of ductile pitted fracture. The core of the specimen has a ductile pitted structure.

Figure 1b shows the fracture structure of the surface layer of a carbonitrided specimen with the maximum impact strength, 80 J/cm² (cycle 3). A defect zone characteristic of the carburized specimen is absent in the thin surface layer and a ductile character of fracture is observed in the whole case. Fracture occurs in finely dispersed precipitates of carbonitride phase uniformly distributed in the ductile (pitted) fracture (Fig. 1d).

In the carbonitrided specimens with an impact strength of 51 J/cm² (cycle 4) ductile fracture is observed only in the surface layer. At a distance of 0.3-0.4 mm from the surface ductile fracture is replaced by preferential fracture in the grain boundaries. With a decrease in impact strength to 37 J/cm² (cycle 5) the quantity of intergranular fracture in the specimens increases (Fig. 1f).

In this case together with ductile fracture, fracture in the grain boundaries, in which precipitation of carbonitride phase occurs, is observed in the cases in a large quantity.

From Table 2 it may be seen with a decrease in impact strength from 80 to 37 J/cm² there is an increase in the degree of defectiveness of the carbonitrided case. With an impact strength of 80 J/cm² there are no defects in the case, with α = 51 J/cm² defects in the form of fine dark inclusions (micropores) appear in the case, and with α = 37 J/cm² defects in the form of a dark constituent are observed in the surface layer. The degree of defectiveness of the carbonitrided case may be judged from the content of molecular nitrogen, the quantity of which increases from 0.15 to 0.46% with a reduction in impact strength from 80 to 37 J/cm².

The core of the carbonitrided specimens treated to cycles 3-5 has a ductile pitted structure.
Both in carburizing and in carbonitriding specimens with a very low impact strength are observed (cycles 2 and 6). The results of microfractographic investigation showed that the fractures of both specimens have a similar structure. Figure 1e shows the structure of the surface layer of a carburized specimen with an impact strength of 9 J/cm². Intergranular fracture occurring in the boundaries of coarse grains is observed across the whole thickness of the carburized case. There is a large quantity of precipitates of carbide phase at the grain boundaries. The core of the specimens has a brittle structure.

A metallographic investigation was made to explain the reason for such a form of fracture. It showed that in the surface layer of the carburized and carbonitrided specimens there are defects in the form of a troostite network at the grain boundaries spread over the whole thickness of the hardened case. The formation of this defect may be explained by the fact that under the given hardening conditions a finely dispersed carbide phase is formed at the grain boundaries in quenching, which leads to a reduction in the hardenability of these zones of the case as the result of the decrease in the alloy content of the solid solution and the appearance in them of the products of the nonmartensite transformation [3, 4].