3. Cast iron with spheroidal graphite whose matrix consists of a structural mixture of bainite, martensite, and retained austenite, with a predominance of martensite, is susceptible to premature failure.

4. The reduction of the amount of retained austenite with prolonged isothermal holding times leads to a reduction of the ductility; the strength characteristics decrease negligibly in this case.

5. The isothermal bainitic transformation is divided into three stages that differ in the average rate of the transformation.

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STRUCTURAL STRENGTH OF MALLEABLE IRON WITH DIVORCED PEARLITE

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Ferritic malleable iron with relatively high ductility (δ = 6-12%) and low strength (σ_b = 30-37 kgf/mm^2) and pearlitic malleable iron with high strength (σ_b = 45-63 kgf/mm^2) and low ductility (δ = 2-6%) are produced at the present time (GOST 1215-59). Nevertheless, malleable iron with divorced pearlite is not widely used in industry, despite its high strength and ductility (σ_b = 45-60 kgf/mm^2, δ = 6-10%). This is probably due to the fact that little research has been done on its structural strength.

The structural strength of a material refers to the combination of properties most completely characterizing the working capacity of machine parts (service life in combination with reliability) [1].

Malleable iron is widely used in manufacturing farm machinery. Many parts of such machines operate under conditions of repeated impact loads. The strength of malleable iron subjected to repeated impact loads cannot be judged from the ultimate tensile strength, relative elongation, or hardness. For proper determination of the working capacity of malleable iron under such conditions it must be subjected to repeated impact tests [2].

We tested malleable iron with divorced pearlite and, for comparison, ferritic malleable iron and ferritic–pearlitic malleable iron and lamellar pearlite. All malleable irons were obtained from white cast iron of the same chemical composition and melted under plant conditions to obtain ferritic malleable iron.

The microstructure and mechanical properties of the iron are given in Table 1.

The impact–fatigue strength was tested on a machine of the lever–impact type designed at the Central Scientific-Research Institute of Heavy Machine Construction (TsNIITMASh), with use of unnotched samples 10×10×55 mm. The samples were subjected to one-sided impact bending under repeated loads with a frequency of 194 impacts per minute (distance between supports 50 mm, impact energy A = 5-20 kgf-cm). The impact energy was determined as the product of the weight of the falling load and the height of the drop. The

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TABLE 1

Sample No.	Microstructure of metallic matrix	σ_b, kgf/mm^2	δ, %	HB
1	Divorced pearlite	60–63	6	219–229
2	Divorced pearlite	45–48	8–10	177–184
3	Lamellar pearlite	59–63	3–4	229–241
4	Ferrite–pearlite	38–40	8–10	156–173
5	Ferrite	34–37	10–12	142–156

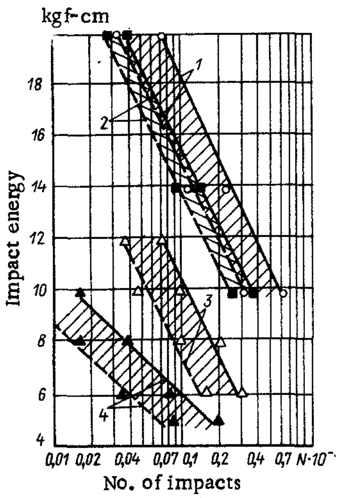

Fig. 1

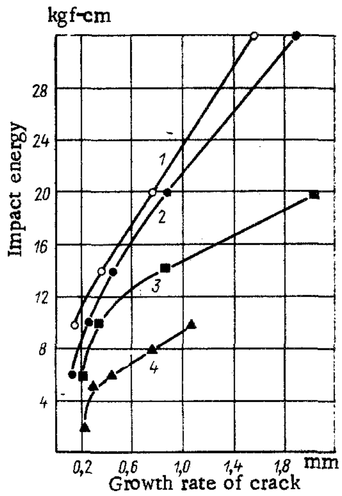

Fig. 2

Fig. 1. Life of malleable iron at different impact energies. 1) With divorced pearlite; 2) lamellar pearlite; 3) ferrite–pearlite; 4) ferrite. ——) Cycles to failure; – – –) cycles to beginning of crack nucleation.

Fig. 2. Growth rate of impact–fatigue crack in relation to impact energy for malleable iron with different structures. 1) Divorced pearlite, σ_b = 60-63 kgf/mm^2; 2) divorced pearlite, σ_b = 45-48 kgf/mm^2; 3) lamellar pearlite; 4) ferrite.

impact–fatigue strength was taken as the number of impacts the sample withstood without fracture at a given impact energy.

The impact–fatigue resistance of malleable iron with divorced pearlite with A = 12 kgf-cm was 10 times higher than that of ferritic malleable iron; with A = 12 kgf-cm the ferritic iron is rapidly deformed and fractured, while the malleable iron has a fairly high impact–fatigue strength [3].

A significant characteristic of the service life of a material operating under repeated impact loads is the so-called "life", which is the operating time of a part with repeated impact loads from the beginning of the formation of a fatigue crack up until fracture [4].

The life was determined as the number of loading cycles from the beginning of crack formation to fracture.

Figure 1 shows the life of various malleable irons. The distance between the solid and dashed lines defines the life of the iron, i.e., the number of cycles withstood by a sample with a crack.

It can be seen from Fig. 1 that the life of malleable iron with divorced pearlite is double that of malleable iron with lamellar pearlite, which indicates the greater reliability of malleable iron with divorced pearlite. Ferritic and ferritic–pearlitic malleable irons have a longer life at relatively lower impact energies than malleable iron with divorced pearlite.

The life of malleable iron is also defined as the growth rate of a fatigue crack, determined as the quotient from dividing the depth of the fatigue crack by the number of cycles. The growth rate of the crack vs impact energy is shown in Fig. 2. It can be seen that the growth rate of the fatigue crack is very high for ferritic malleable iron and very low for malleable iron with divorced pearlite. Thus, the low growth rate of the fatigue crack in malleable iron with divorced pearlite is responsible for the longer life of machine parts operating with an already formed crack, and thus the higher reliability under operating conditions.

The growth rate of the crack varies with the strength of the malleable iron. The growth rate is lower in the iron with higher strength (Fig. 2, curve 1) despite its somewhat lower ductility.

Thus, malleable iron with divorced pearlite, with a longer service life and greater reliability than ferritic malleable iron, has a higher structural strength in operation under conditions of repeated impact loads.

CONCLUSION

To increase the structural strength of machine parts made of malleable iron, it is expedient to anneal them to divorced pearlite.

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RESISTANCE TO FRACTURE OF GRAY CAST IRON PIPE

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The resistance of gray cast iron pipe to hydraulic pressure depends, to a considerable extent, on the casting procedure and the operating conditions. Pipes produced by casting in sand molds in a low-productivity rotary apparatus (stationary casting – SC) do not fail under a pressure of 40 atm, while pipes cast by the centrifugal method (CC) often crack under hydraulic pressure [1].

To determine the operating characteristics of castings under static loads it is necessary not only to determine the strength but the resistance to brittle fracture. At the present time this criterion is taken as the fracture toughness K_{Ic} determined on notched samples under conditions of plane strain in tension [2, 3]. The values of K_{Ic} were determined on notched samples $100 \times 10 \times 2$ mm and calculated by the formula

$$K_{Ic} = K_0 \cdot \sigma_N \sqrt{\pi l},$$

where K_0 is a coefficient taking into account the free surface (according to Gross [2]), which was taken as equal to 1.7 for SC castings and 2 for CC castings; σ_N is the normal breaking stress; l is the notch depth, equal to 1.8 mm. The radius of curvature of the notch $r_n = 0.27$ mm.

The samples were prepared (10-12 pieces for each variation) from commercial pipe produced under the following conditions:

SC-1, cast in sand molds in a rotary apparatus (stationary casting);

CC-2, cast by the centrifugal method in a metallic water-cooled chill mold with subsequent heat treatment at 880°C for 20 min, with furnace cooling to 500° followed by cooling in air;

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