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# GRADIENT HARDENING CHISEL PLOW FROM NODULAR IRON

L. V. Kostyleva[1, 2], A. S. Ovchinnikov[1], D. S. Gapich[1] and S. D. Fomin[1]
[1]Volgograd State Agrarian University (VolGAU), Volgograd (Stalingrad), Russia
[2]Volgograd State Technikal University (VolGTU), Volgograd (Stalingrad), Russia
E-mail: fsd_58@mail.ru

## ABSTRACT

For plowing hard soils littered with stones, used plows overlaid with a chisel. Chisel must possess high wear resistance and impact resistance. To improve the durability of the bit in harsh environments need to ensure mechanical properties radically different parts of zones. For such a distribution structures necessary to carry out very complex multistage thermal treatment. Theoretically proved and experimentally confirmed the possibility of formation of the given structure and properties of the zones of ductile cast iron products with a volumetric heating of blanks with regard to the technology of mass production. Taking into account the existing structural in homogeneities in the castings the optimum heating temperature for quenching is 880÷900°C with duration of exposure 2.5-3 hours. To obtain the desired structure and properties of the hardened casting zone for use as the quench liquid water heat treatment must consist of at least three cycles of "cooling - self-heating" from the duration of cooling in the first cycles of 1-2 seconds.

**Keywords:** plowing of stony soils, plow overhead bit, ductile iron, complex technology heat treatment, bainite, martensite.

## INTRODUCTION

For the most heavy duty plowing hard soils littered with stones, used to overhead chisel plows, which is attached to the toe plowshares, speaking for him at 30 ... 40 mm. Chisel subjected to intensive wear and perceives high dynamic loads during a meeting with rocks, so it must have high wear resistance and impact resistance.

As the wear of the bit is reset by pushing the edge of the blade, making it difficult to form the mounting parts and components as a whole.

To improve the durability of the bit in harsh environments need to ensure mechanical properties radically different zones of the details (Figure-1.)

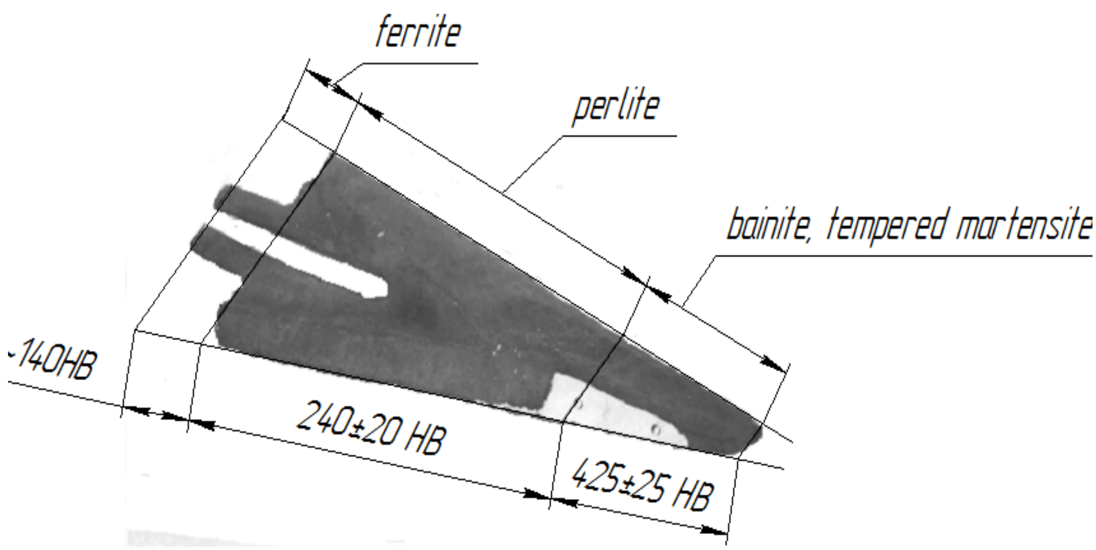


**Figure-1.** A general view of the casting chisel plow with the boundaries of the zones desired structure and properties.

The nose of the drill bit, is actively cooperating with the abrasive medium, a length of 70 mm should be hardened to HB 400...450. In the central area is necessary to reduce the hardness of HB 220...260 to provide the necessary details of Shock. To prevent brittle fracture of the thin locking elements shank hardness thereof does not exceed HB140.

The chisel plow produced by casting of ductile cast iron, which is widely used in the world (Bartosiewicz *et al.*, [2]; Panneerselvam *et al.*, [8]; Schoenborn *et al.*, [10]).

In casting the bit having a complex form alternating tapered section due to the different speed of cooling in a state after molding heterogeneous structure formed from ferrite-pearlite in a central portion of the

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article to the presence of pearlite cementite eutectic in the cutting edge and the shank, which does not give a desired hardness distribution, and it must be corrected by heat treatment.

As a result of the heat treatment in the central part of the casting to be obtained pearlite structure metal base iron elements in thin shank - ferritic or ferritic-pearlitic, and the working part of the nose should be tempered martensite or bainite (Figure-1).

For such a distribution structures necessary to carry out very complex multistage thermal treatment, including:

- graphitizing annealing of structural free cementite eutectic;
- normalization to eliminate ferrite and pearlite structures to obtain the most massive parts of the central portion;
- hardening of the working area of the nasal and tempered to form a structure in it bainite or tempered martensite;
- local joke locking elements on the ferrite-pearlite structure of the metal base.

Thus only graphitizing annealing, normalization may be performed with volumetric heating throughout the casting and subsequent hardening, tempering and annealing of locking elements involve zonal heating of the product, that is individually heat treatment makes this order uneconomical for mass production. Development of a new complex technology heat treatment of castings performed bit in terms of mass production based on the high demand and stable product quality.

Since the heating temperature for normalization is quite sufficient for conducting and tempering and annealing, studied the possibility of holding all the necessary set of technical operations with a volume of heating products in methodical walk-through ovens.

Castings placed on pallets with special multi-holes, which were drowned thin tails bits. Analysis and experimental verification showed that the amount of heat accumulated by a massive pan baking, is quite sufficient for annealing on ferrite-pearlite structure in thin-walled castings and components to protect them from hypothermia during subsequent manipulation with intense cooled other parts of the bit.

However, the heat radiation of the heated pan so large that it can prevent the massive central part of the normalization of castings, cooled in air, and it, together with perlite and ferrite can be formed, reducing the hardness of a predetermined.

If the combined annealing, normalizing and tempering, conducted for different zones of the casting at the time, an additional heat removal from the items via quenched accelerate the cooling of the area is normalized, but will not affect the liner joke.

Thus, additional terms of the customer by ferrite and pearlite in the shank is not in the zone hardenable items can be implemented in a single heat treatment operation.

Since hardenable bit plow portion has a tapered shape with a sharply varying cross-section, normal cooling by dipping it in a quenching fluid with full cooling to room temperature leads to the formation of elevated but irregular hardness also dramatically increase the thermal stresses and the likelihood of formation of hardening cracks (Aleksandrov *et al*., [1]).

In Fedjukin [4] shows the significant reduction in thermal stress at high temperature thermal cycling treatment (VTTSO) cast iron.

To fulfill the specific requirements on the structure and hardness of the working part of the nasal products and exclusion probability of formation of hardening cracks in a heat treatment of heating was applied intermittently, cyclic hardening with autotempered.

Discontinuous, cyclic hardening was selected based on the initial temperature of heating, cooling capacity of quenching medium, the thickness of the body in the area of hardenable casting and sensitivity to thermal stresses. However, such heat treatment regimes should be tightly regulated in temperature and time as well as any changes to these parameters will be accompanied by an increase or decrease in hardness with respect to its predetermined values.

However, the fundamental ability to perform all the operations of such heat treatment for a period of time between successive pushing pallets in a continuous furnace is real, but it requires special manufacturing quenching installation.

The theoretical possibility of obtaining stable high-quality products in the quantities required makes this technology suitable for mass production after the necessary studies and trials.

## MATERIALS AND METHODS

For optimal mining technology hardening method the piece of work provides heat treatment of castings "chisel plow" with volumetric heating in the shaft furnace simulator Industrial quenching installation (Figure-2).

Casting, attached to the pallet, heated in a shaft furnace, and then inserted into the slot hardenable part of a special screen so that the protruding through the screen of the equal length, which is necessary to produce hardening.

In this position the item immersed in the quenching fluid to the screen briefly for a few seconds, followed by a brief, as measured in second's exposure to air. During this exposure, the details of the cooled part was heated to a predetermined temperature, which is monitored by luminescence (color incandescence) and using a temperature indicating crayon. After self-heating cooling cycle is repeated.

In the course of the experiments studied the effect on the quality of the hardened zone the following factors:

- the heating temperature for quenching and exposure time;
- the duration and the amount of cooling cycles - self-heating;
- type cooling (quenching) liquid as that investigated

water, 5% sodium silicate solution, a 2% and 1% aqueous-alkaline solutions methacrylonitrile UZSP copolymer-1.

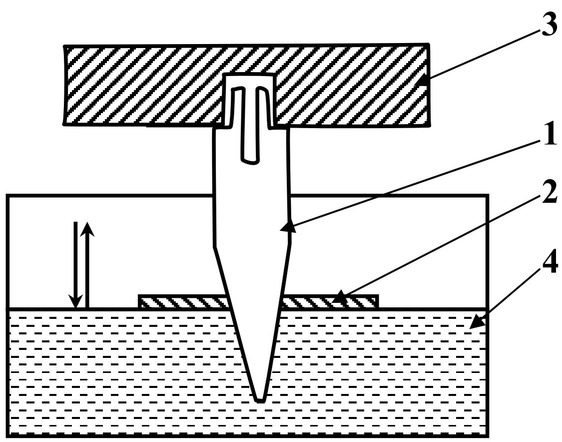


**Figure-2.** Scheme quenching experimental castings 1 - casting; 2 - the screen; 3 - pan; 4 - hardening bath.

Quality hardening on experimental products was estimated by measuring the express them Brinell hardness at the side of the plane, and in some cases, metallographic studies.

With the positive results of heat treatment experiment was repeated at the party castings for the detection of stability achieved at the given parameters of hardening technology.

Austenitizing temperature was determined based on the maximum content of silicon in the casting (2.6-2.8%), established by chemical analysis, and the need for complete dissolution structurally free cementite during the stay of the pallet with the ingots in the hot zone of the furnace.

At 15 trays in the oven and pushing cycle maximum duration of 15 minutes of heating product was 3 hours 45 min., and the time austenitizing - 2.0-2.5 hours. Since, based on the content of silicon austenitizing temperature is about 830°C, and dissolution of carbides at this temperature for 2.5 hours not occur adopted working temperature 920-930°C, for most castings somewhat high, but it allows to work without pre-grading of the original cast structure.

From the viewpoint of ensuring normal shank annealing temperature of 930°C it is too high, so it does not allow obtaining a pure ferritic structure due to accelerated cooling and the temperature would preferably 860-830°C, but the quality is not ensured quenching.

Thus, the selected surround mode heating: T = 900°C, while in the oven 3 hours 45min. Provides a complete austenitizing iron and the necessary conditions for the subsequent heat treatment.

Cooling mode intermittently-cyclic hardening should ensure that the structure and uniform hardness throughout the volume of hardenable zone, despite the fact that it has a variable cross-section.

The duration of cooling in the first cycle must ensure supercooling of austenite at the thinnest section at the length - 25÷30 mm, which bainite transformation begins and, after cooling in the quench liquid. Time course of bainite transformation in the first section of the reinforcing regulated resistant austenite more massive parts and must be calculated so that the beginning of the following cycle of cooling temperature there was sufficient for tempering.

In the calculation considered two sectional area hardenable bit: 3.5 mm thick and 6.5 mm, respectively, are located at a distance of 7 mm and 13 mm from the cutting edge. According Popov [9] while cooling the steel billet from 920°C in water temperature divided by the cross section of the cooled preform according to the curves in Figure-3.

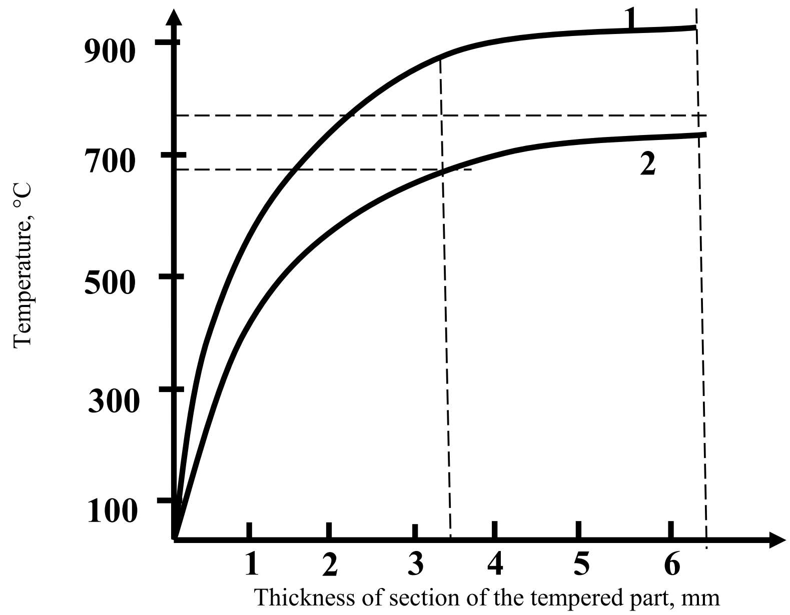


**Figure-3.**The temperature distribution over the cross section of the steel billet during cooling from920°C (Curve 1) and 780°C (Curve 2) for 2 seconds in water.

Consequently, the minimum cross-sectional thickness of 3.5 mm after 2 seconds, the limit condition of the possibility of bainite transformation and autotempered.

More massive (> 6,5 mm) cross section while maintaining the ability to quench as exposure contributes to self-heating of the array of metal from the internal heat to hardening temperature.

An analysis of the temperature distribution over the cross section of the casting with cooling water in view of transformation kinetics of supercooled austenite ductile iron (Palatkina *et al.*, [7]) showed that, at least in the first cycle intermittently cyclic-hardening estimated duration of exposure to water (quenching) should be 1-2 seconds, and the air (autotempered) - 3-5 seconds (Kostyleva *et al.*, [6]). Clarification of temperature and time settings intermittently-cyclic hardening was performed experimentally on real castings.

## RESULTS

During the experiment, the temperature of the heating and cooling kinetics varied within the limits specified in Table-1.

**Table-1.** The parameters of heat treatment experienced chisel plow.

| Number mode | The temperature of the heating furnace, °C | Time cold before quenching, second | Cooling mode of working of the bit | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | Number of cycles | Cooling time in the water / air, second | | | | |
| | | | | 1st m | 2nd m | 3rd m | 4th m | 5th m |
| 1 | 900 | - | 2 | 2/4 | 4/60 | | | |
| 2 | 930 | - | 2 | 4/4 | 5/600 | | | |
| 3 | 930 | - | 3 | 2/2 | 2/2 | 5/600 | | |
| 4 | 930 | - | 3 | 2/2 | 2/3 | 8/420 | | |
| 5 | 930 | 15 | 3 | 1/1 | 3/4 | 8/500 | | |
| 6 | 930 | 35 | 3 | 1/3 | 8/15 | 15/300 | | |
| 7 | 930 | 500 | 1 | 9/400 | | | | |
| 8 | 930 | 15 | 5 | 1/1 | 1/1 | 1/1 | 1/5 | 150/0 |
| 9 | 930 | 15 | 4 | 1/2 | 2/4 | 4/6 | 90/0 | |
| 10 | 930 | 15 | 3 | 1/10 | 6/15 | 40/560 | | |
| 11 | 880 | - | 5 | 1/2 | 1/2 | 1/2 | 1/10 | 120/0 |

At the end of intermittent cyclic cooling of the working bit cooled to darkening in the position of cooling water in the bow.

Since the broken-bit cyclic hardening is carried out in a matter of seconds the bulk of the products and the shank inserted in the tray at the same time retain the high temperature austenitic region, and they do not occur in this short time almost no transformations.

Normalization of the middle part of the product and the shank ferritization defined transformations taking place in the same temperature $\gamma-\alpha$ area: iron for this brand is 800÷760°C (Popov and Popova, [9]), but requires a normalization of hypothermia, and annealing takes place in conditions close to equilibrium.

Accordingly, after intermittent-cyclic hardening and subsequent autotempered part must be immersed into the quenching liquid hardenable the entire depth of the zone and the central part of the workpiece between the pallet and the screen to blow compressed air until it reaches the supercooling of austenite to 760÷740°C, which is the formation of structure in the normalization of gray cast iron (Popov and Popova, [9]; Bunin and Taran, [3]).

Under the conditions of the experiment implemented a change in temperature of the central part of the cooled compressed air, controlled by the color of the glow. Dark cherry glow corresponding to 760÷740°C (Filinov and Firger, [5]) is achieved within 10÷12 minutes.

After another 2-3 minutes in the still air cooling the product can be unloaded in a container and pallet flow to the load of subsequent batches of parts.

The cheapest and affordable quenching medium - technical water for this technology has a very high cooling capacity, because that requires a very precise adjustment of pneumatic injection and discharge of the water level in a quench bath to within 0.5÷1.0 seconds. Therefore it was investigated and other incombustible liquid quenching with milder quenching effect: aqueous solution of sodium silicate (5%), and 1% to 2% aqueous solutions of the polymer UZSN 1.

Preliminary experiments involve immersing hardenable bit part in the quenching liquid to cool the casting to control the cooling time and the resulting hardness of the hardened zone.

In pure water, cooling to a dark color lasted 60 seconds, and the details of the increased hardness of the tempered NV514, but were amazed quench cracks. At 2% and 1% solutions UZSP cooling to the same degree of browning was slowed to 180 seconds, and 150, respectively, quench cracking is not formed, but the hardness of the hardened zone was lower than required by the drawing.

The water glass solution (5%) showed an average cooling time between the water and solutions UZSP - namely, 120 seconds, and deliver results of hardness close to the desired value.

However, the instability of the solution concentration of the solute burn on hot items, which requires constant monitoring of its actual content of the quench liquid makes on the path of tightening cooling and used as the quench fluid process water.

**DISCUSSIONS**

The results of the pilot study carried out in order to optimize discontinuous-cyclic hardening on experimental details "chisel plow", are presented in Table-2.

**Table-2.** The microstructure and hardness of the hardenable components experienced "chisel plow" treated by mode 1÷11.

| Number mode | Hardness at a distance from the cutting edge of the bit, HB | | | The microstructure of the hardening zone | Note |
|---|---|---|---|---|---|
| | 20mm | 40mm | 70mm | | |
| 1 | 460 | 415 | 415 | Bainite | |
| 2 | 477 | 415 | 321 | Tempered martensite, bainite, troostite | |
| 3 | 444 | 415 | 340 | Bainite, troostite | |
| 4 | 477 | 444 | 401 | Tempered martensite, bainite, troostite | |
| 5 | 450 | 415 | 400 | Bainite, troostite | |
| 6 | 461 | 444 | 444 | Bainite | |
| 7 | 388 | 415 | 415 | Bainite, troostite | |
| 8 | 510 | 477 | 477 | Martensite, bainite | Cracks in the hardened edge zone |
| 9 | 415 | 390 | 300 | Bainite, sorbitol | |
| 10 | 480 | 480 | 480 | Tempered martensite, bainite, troostite | |
| 11 | 444 | 444 | 444 | Bainite | |

As seen from Table-2, the results of the intermittently-cyclic hardening by quenching with autotempered depend on the heating temperature, duration of exposure and the self-heating of water in each cycle and the number of cycles.

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High temperature (930°C) in heating mode 2, 4, 8 for different parameters of the cooling gave usually increased hardness in a thin section of extreme.

Cooling the items after bulk heating to 930°C in air for 15÷35 seconds, during which most actively cooled only extreme thin part bit alignment was the hardness hardenable part at the desired level (Modes 5 and 6). Increasing the time to 50 seconds cooling irrational, since this part is too thin supercooled and quenched to a desired hardness of the subsequent cooling in water.

Reduced volumetric heating temperature to 880°C (with natural cooling for 10 seconds necessary for transferring the items from the furnace into the quench unit) has responded positively to the uniformity and the hardness of hardened parts (mode 11).

From the analysis of the experimental results shows that the most homogeneous hardness in the range 425 ±25 HB be achieved with a large number of cooling cycles (at least 5) with short time-periods of immersion in water, especially in the early rounds (about 1÷2 seconds), and short duration of exposure to air (2÷3 seconds) (mode 11).

Cooling time in the water and exposure to air can be increased, but not in the first cycle, under these conditions the number of cycles can be reduced without compromising the quality of the hardening (Table-1 Case 5).

At best, intermittent modes with cyclic hardening (version 5 and 11 of Table-1) was treated with the party bits of 10 pieces.

Figure-4 shows the character of the distribution of hardness HB products in the zones corresponding to these areas of the structure shown in Figure-5.

Throughout the area, are exposed intermittently-cyclic hardening (on the length of 70 mm from the edge of the work) microstructure of a lower bainite with a hardness of 400-450 HB.

The central part of bits has hardness in the range of 200-260 HB pearlite structure and metal base.

The metal base tail bits fixing section together with perlite present at least 40% of ferrite and the hardness was within 124-138 HB.

Thus, the results of hardening of castings bit plow treated by the proposed technology heat treatment of heating, fully comply with the drawing of zonal distribution of hardness and microstructure.

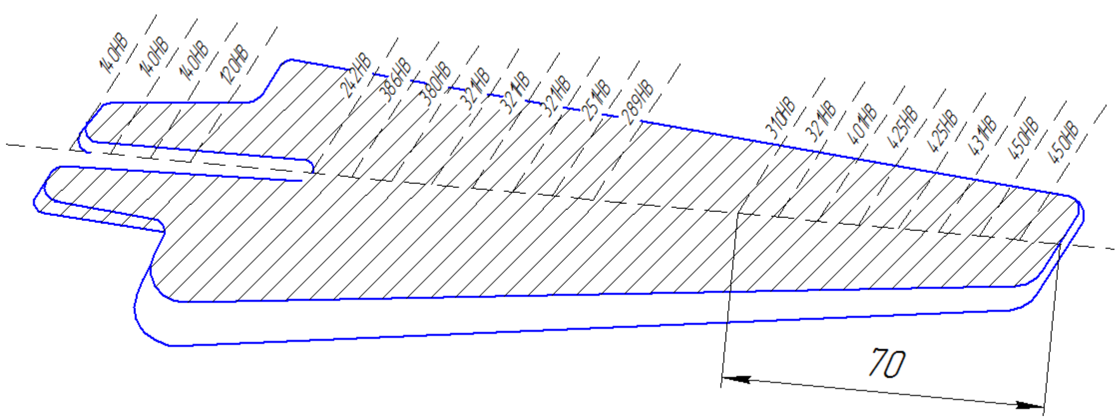
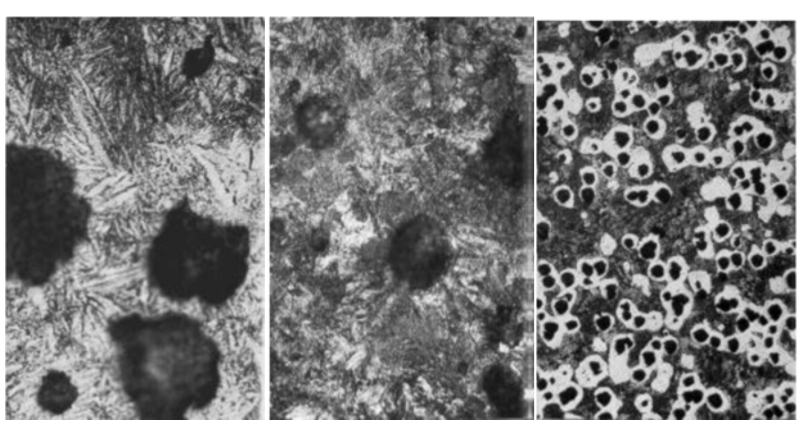



**Figure-4.** The scheme of distribution of hardness in the zones bit.



a b c

**Figure-5.** The microstructure of the metal base "bit rogue" heat-treated according to the proposed technology: *a* - bainite in the work area, ×500; *b* - pearlite in the middle part, ×300; *c* - ferrite and pearlite in the fastening portion (shank), ×100.

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## CONCLUSIONS

a) Theoretically proved and experimentally confirmed the possibility of formation of the given structure and properties of the zones of ductile cast iron products with a volumetric heating of blanks with regard to the technology of mass production.
b) Taking into account the existing structural inhomogeneities in the castings the optimum heating temperature for quenching is 880÷900°C with duration of exposure 2.5-3 hours.
c) To obtain the desired structure and properties of the hardened casting zone for use as the quench liquid water heat treatment must consist of at least three cycles of cooling - self-heating to the duration of cooling in the first cycles of 1-2 seconds.

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