USE OF LOW-HARDENABILITY STEEL IN
SMALL-SCALE PRODUCTION

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At the present time automobile and tractor plants using LH (low-hardenability) steels for manufacturing large numbers of heavily loaded machine parts (gears, piston pins, etc.), which are usually manufactured from carburized alloy steels.

The special characteristic of LH steels is that in quenching gear teeth and other such thin elements of machine parts the piece is not hardened clear through despite the fact that it is heated through. The surface is hardened to HRC 58-62 to a depth of 1-2 mm and has the properties of a carburized hardened layer. The core is hardened to HRC 30-40 and has the properties of quenched and tempered structural steel.

A high cooling rate for LH steel after induction heating requires complex and costly equipment whose use is justified only for mass production. Furnace heating is more economical than induction heating for small-scale production.

We investigated bulk quenching with furnace heating of cylindrical samples with diameters of 12.5 x 80, 12.5 x 40, 16 x 40, and 20 x 40 mm. The samples were prepared from steel 55PP (0.57% C, 0.12% Mn, 0.20% S, 0.033% Cr, 0.01% P) from the Donets Metallurgical Plant.

Bars 130 mm in diameter were forged into rods 25 mm in diameter and 400 mm long (forging temperature 1000-1050°C); they were normalized 1.5 h at 850-860°C.

The samples were quenched from 770, 790, 800, 830, 860, and 900°C after holding 5, 10, 15, 20, and 30 min in an MP-2U electric furnace and a salt bath (77.5% BaCl₂ + 22.5% NaCl) based on a TÉP-1 laboratory furnace. Cooling was in water at room temperature and in 5% NaOH and 10% NaCl. Three methods of placing the samples in the cooling medium were used: the samples were thrust rapidly into the cooling medium, allowed to drop, or transferred smoothly on hangers.

The optimal heat treatment conditions were selected on the basis of the macro- and microstructures, hardness, and hardenability. The microstructure of the quenched samples was examined in the MIM-8 microscope. The microsections were etched in the standard reagent (4% HNO₃ in alcohol). To reveal troostite the samples were polished and etched in "triple" reagent.

![Fig. 1. Variation of hardness of surface (1) and core (2) of 55PP samples in relation to quenching temperature and holding time.](image-url)
The results are shown in Fig. 1, where it can be seen that when quenched by thrusting in water the maximum hardness decreases and the difference in hardness increases with increasing quenching temperature and holding time; the hardening is patchy (for HRC 43 and lower). This is due to decarburizing of the surface as the result of heating in an oxidizing atmosphere and insufficient quenching capacity of the water when the sample is thrust into it. The structure was heterogeneous — fine and medium needles of martensite (grade 4–5), temper troostite, and pearlite with small sections of martensite and ferrite. The structure of the core was troostite with individual fine grains of ferrite. On heating steel 55PP from 770 to 845°C the grain size changes slightly (grade 5–7), while above 845°C the grain size increases sharply, reaching grade 2–3 at 860–900°C. From 770 to 845°C the size of martensite is grade 5–6, and at 860–900°C grade 7–8 (Fig. 2).

Grain growth begins at 840–850°C; higher temperatures are not recommended for bulk quenching. The experiments also made it possible to determine the effect of quenching temperature and holding time on the hardenability of steel 55PP (Fig. 3). With heating above 860°C the hardenability increases due to grain growth; the hardenability is not affected by holding time. The considerable depth of hardening (0.9–2.7 mm) with a holding time of 5 min is due to insufficient heating and the cooling rate. The least difference in hardness resulted from quenching in 10% NaCl. The depth of hardening was 2.7–3.2 mm for quenching in water, 2.5–3.0 mm in 10% NaCl and 3.0–3.4 mm in 5% NaOH (Fig. 4).

Thus, the most effective cooling medium for bulk quenching of steel 55PP was 10% NaCl, which provides more uniform hardening with slightly lower hardenability.

The microstructure of samples quenched in 10% NaCl and 5% NaOH was identical — medium-size martensite (grade 5–6) in the hardened zone, martensite and temper troostite in the transition zone, and sorbite with sections of martensite and individual grains of ferrite in the core.

It was found that for bulk quenching of steel 55PP both thrusting the samples into the tank and letting them drop into the tank result in a satisfactory cooling rate and hardening (Fig. 5).

The depth of hardening varies with the method of placing the samples in the quenching medium. The depth of hardening was highest for thrusting the samples into the tank and dropping into a tank of sufficient depth (which must be taken into account). When the samples are thrust into the tank or dropped into a tank of sufficient depth the 10% NaCl solution is expedient for bulk quenching of steel 55PP. The existing equipment can be used — electric chamber furnaces, shaft furnaces, etc., and quenching tanks.

Because the accepted quenching media (10% NaCl and 5% NaOH) are characterized by a high cooling capacity at temperatures from 300 to 200°C, and thus can induce additional stresses, the distortion of the samples was checked after quenching.

The effects of the quenching medium and the method of placing the samples in the quenching medium on the distortion were checked with samples of 55PP steel 12.5 mm in diameter and 80 mm long. They were quenched from 790–800°C and 850°C in water, 5% NaOH, and 10% NaCl. They were thrust into the tank and dropped into the tank. For all three quenching media the samples thrust into the tank had a deflection of 0.09–0.11 mm, while the deflection of samples dropped into the tank was 0.32–0.42 mm.

To determine the effect of sample size on the depth of hardening we used samples of steel 55PP with diameters of 12.5, 16, and 20 mm. For the samples quenched from 790–800°C (holding 15 min) in 10% NaCl the maximum (surface) hardness was identical (HRC 64). The difference in hardness between the surface and depth of the hardened layer decreases with increasing diameter of the sample. With a surface hardness of HRC 64, the minimum hardness was HRC 56 for samples 12.5 mm in diameter, HRC 58 for samples 16 mm