Heat treatment lines. a) A 21-tray muffle-free line for carburizing and nitriding; b) a 48-tray muffle-free line for carburizing and nitriding; c) an 18-tray line for carburizing and nitriding; d) a muffle-free line for complex chemico-thermal treatment of chromium–nickel steel parts. 1) Pusher; 2) loading tambour; 3) carburizing furnace (d) or nitriding furnace (a, c) with horizontal radiant tubes; 4) unloading tambour (a, b), extractor (c, d); 5) oil tank for quenching at 160-180°C (a, b), transmission mechanism (c), cooling corridor with transmission mechanism (d); 6) auxiliary tank (a), unloading transmission mechanism (b), pusher (c, d); 7) screw tray extractor (a), one-row washing machine (b), cooling corridor with double walls (c), two-row quenching and tempering muffle-free furnace (d); 8) transmission tank with cold spindle oil (a), one-row tempering furnace (b), unloading tambour (c), hot oil quenching tank (d); 9) three-stage washing machine (a), transmission mechanism for loading (b), transmission carriage (c), unloading tambour (d); 10) furnace for low-temperature tempering (a), transmission mechanism for unloading (c, d); 11) hydraulic mechanism to move trays (a), washing machine (d); 12) transmission carriage (a), a low-temperature tempering furnace (d); 13) mechanism for moving the transmission carriage (a, d).

**AUTOMATIC EQUIPMENT FOR INDUCTION HEATING AND QUENCHING**

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Automatic equipment for production lines has become a necessity because of the mass production of machine parts in the hundreds of tons [1].

Below we describe some typical induction furnaces together with the quenching equipment developed by the electrothermal section of the Moscow Automobile Plant. This equipment may be of interest in machine construction plants where the use of high-frequency equipment is projected.

**Automatic Equipment for Induction Heating and Quenching of Small Cylindrical Parts**

The quenching of small cylindrical parts after induction heating must be completely automatic.

In equipment for automatic quenching high-frequency generators must be used as much as possible. For this purpose the parts should not be cooled in the inductor but by a separate sprayer. It is also necessary that the interval between two heating cycles (during which one machine part passes from the inductor into the spray and another is placed in the inductor) be as short as possible. For this high-speed operation a control drum turned by an electric motor should be used.
Figure 1 shows an automatic apparatus used for transmission synchronizer pins of the ZIL-130 automobile.

Several thousand of these synchronizer pins are made every day. The pins are loaded in a vibrating bunker (to the left in Fig. 1), the pins moving into single file as they move up the spiral of the bunker. The vibration is produced by an eccentric collar on a shaft rotated at 970 rpm by a 0.4 kW electric motor. From the top of the bunker the pins slide down an inclined tube into the heat treatment apparatus one by one. The pins are heated by the high-frequency inductor, cooled by a spray, and ejected from the apparatus (see Fig. 2). As can be seen in Fig. 2, from the tube, 1, the pin, 2, passes into a collar 3 fixed at the end of a bar 4. In Fig. 2 the collar is shown in its extreme position, lined up with the tube, where it receives a pin. When the rod moves to the left the pin drops into the inductor 5, which has a lining 6 made of heat-resistant plastic, and a sliding red 7 at the bottom holds the pin there while it is being heated.

The inductor is heated continuously during operation of the apparatus. When the time required to heat the pin to quenching temperature at a given depth has elapsed, the bar 7 moves to the left and the pin drops into the upper part of the sprayer 8 where it is held by a bar 9. When the proper heating time has elapsed and the pin is ready to be dropped out of the inductor the intensity of the current in the inductor is momentarily decreased by the automatic connection of an additional resistor in the generator circuit to prevent the pin being held by the electromagnetic field of the inductor. When the bar 9 moves to the left the pin drops into the lower part of the sprayer 8, where it is stopped by a fourth bar 10. When the bar 10 moves to the left the quenched pin drops from the sprayer onto a conveyor.

Thus, the heating time and the quenching time are controlled by the movements of four bars, 4, 7, 9, and 10. These bars are moved by levers tripped by pins on the control drum rotated by a 1 kW motor through a reducing gear with replaceable gears. The conveyor is operated by the same drum. The pins on the control drum which control bars 4 and 9 are permanently fixed, while the pins controlling bars 7 and 10 can be adjusted to vary the heating and quenching times.

This apparatus treats 1400 pins per hour. We use a PVV 100/8000 transformer (100 kW, 8000 Hz) utilizing an average of 80 kW. Each pin is heated to the quenching temperature in 0.9-1 sec. The average heating rate in the temperature range of phase transformations is about 350 deg/sec. The quenching time is 2.1-2.2 sec, which ensures self-tempering, thus eliminating the need for low-temperature tempering.

Heat Treatment of Piston Pins by Induction Heating

We have developed at the Moscow Automobile Plant a new method of rapid heat treatment and continuous quenching for piston pins made of steel No. 45. Two pieces of equipment were constructed to apply this new method.

The essence of the process of rapid heat treatment of piston pins is bulk induction heating to 850-860°C and controlled quenching in an apparatus which prevents the water from wetting the inside of the pins [2]. After quenching, the temperature of the pin becomes uniform at about 400°C (Fig. 3).
In the case of ordinary heat treatment, high-temperature tempering transforms martensite into sorbite throughout the section, whereas in controlled surface quenching the martensite which is formed at the surface in the beginning of quenching is transformed into troostite-sorbite or troostite throughout the section during the time the temperature becomes uniform after quenching. Sorbite is formed in the center of the pins.

Comparisons of the hardness, structure, and strength of pins after ordinary heat treatment and after rapid heat treatment have shown that the hardness is about the same in both cases, while the structure and the strength are identical and satisfy GOST specifications. Three years of mass production of piston pins by this method (10 million pins) has shown the advantages of this method, and therefore it is recommended for use in other automobile and tractor plants.

The apparatus treats 1000 pins per hour. The inductor is connected to a PVV 100/8000 transformer (100 kW, 8000 Hz); the average power consumption is 85 kW.

In the case of surface quenching of the outer surfaces of cylindrical parts (pins) it is necessary to eliminate the deep-quenched layer at the ends of the pins to avoid chipping when thin-walled piston pins are quenched. This effect is a result of the lag of the electromagnetic field at the ends of the pins as they pass through the inductor. This deep-quenched layer at the ends can be eliminated by decreasing the intensity of current in the inductor for a certain time.

Figure 4 is a photograph of the automatic apparatus for continuous quenching of the outer surfaces of piston pins. The apparatus has been used for three years and the results are very satisfactory. The speed of the pins through the apparatus is controlled by an Archimedes screw (Fig. 5) on the same shaft as the commutator. The rigid connection between the commutator and the Archimedes screw makes it possible to decrease automatically the current in the inductor during the passage of the pins through the inductor, and consequently obtain a uniform quenched layer along the whole length of the pin. When the average heating rate at phase transformation temperatures is 350 deg/sec the heating time is 0.85 sec. The time interval between the end of heating and the beginning of quenching is 0.2 sec. The productivity of this apparatus is the same as that of the heating apparatus (1000 pins/h), and the average power consumption is 80 kW (from a PVV 100/8000 high-frequency generator).

**An Automatic Apparatus for Quenching Machine Parts in Different Areas**

In many machine parts there are different areas with different sizes and shapes which must be quenched. An example is the expander cam of a hand brake. The expander must be quenched to a depth of 1.5-4 mm, while the cylindrical surface with two different diameters and lengths must be quenched to a depth of 1.5-3 mm. The hardness of all three surfaces must be HRC 52-62.

There is no problem in quenching these three surfaces separately, but in mass production separate quenching is expensive because of the wasted energy of the high-frequency circuits, the complicated construction of quenching automata (which must then have three different high-frequency circuits), and the complication of transferring the machine parts within the apparatus. It is also more advantageous to induce self-tempering of all three surfaces simultaneously. For this purpose three different sizes of windings must be used in the inductor. Inductors with wind-
Fig. 6. Four-winding inductor for simultaneous quenching of three different areas of hand brake expander cams. 1) Electromagnet; 2) inductor; 3) expander cam. The three areas are marked with heavy lines.

Woundings connected in series are preferable because in this case the results of quenching are less dependent on the quality of weld seams than with inductors in which the windings are connected in parallel. Figure 6 shows such an inductor with four windings for the simultaneous quenching of the three different areas.

Figure 7 is a diagram of the apparatus for quenching expander cams, and Fig. 8 is a photograph of the apparatus. The parts are placed in collars attached to the rotating platform 1 (Fig. 7). The platform holds 72 collars. The movements of the machine parts in the apparatus, the heating, and the quenching are all automatic.

The mechanical arm 2 with an electromagnet 3 seize a machine part on the platform, places it in the inductor 4, and (after quenching) puts it in the tray 5 and returns for another part. The motion of the arm, the rotation of the platform 1/72 part of one revolution after each cycle, and the control of the heating and quenching times are operated by a system of control cams 6 and 7, levers 10 and 11, a friction clutch 12, a ratchet 13 with a spring 14, terminal switches KB, and a pneumatic cylinder 15. The control cams are operated by a 1 kW electric motor 8 through a double worm reducer 9 with changeable gears.

Fig. 7. View of the automatic apparatus for quenching hand brake expander cams. The operations controlled by the various switches are as follows: 11KB) cooling of the electromagnet; 12KB) turns off electromagnet; 13KB) turns off muffle; 15KB) turns on heating; 16KB) automatic cut-off switch activated by the machine part; 17KB) emergency switch.

The heating time to quenching temperature is 4.9-5 sec, the average heating rate at phase transformation temperatures being 100 deg/sec. The quenching time is 5.2 sec, which ensures self-tempering after quenching. The capacity of the apparatus is 180 parts per hour. Three such pieces of equipment can be operated from one high-frequency generator.

Three of these apparatus are connected to the generator in a circuit with a commutator which connects each apparatus to the generator in turn, so that the power of the generator is not wasted between heating cycles in a single apparatus.
A new method of induction heating for surface quenching of gears of medium modulus made of steel of low hardenability was developed at the Moscow Automobile Plant under the direction of K. Z. Shepelyakovskii [3-5].

Steels with low hardenability require very rapid cooling: about 0.1 liter of water per second per cm² (or 100 liters/sec) is needed to quench the surface of gears 300 mm in diameter with teeth 70 mm long, the modulus of the teeth being 6 mm. Therefore, the water supply for this apparatus must be tested and checked to ensure the necessary quantity. The quenching water must be supplied through large pneumo-hydraulic valves. The water tank must be placed in the immediate vicinity of the apparatus or, better, made part of it.

This automatic apparatus has been used for quenching cylindrical gears in the production lines since 1961.

**Semi-Automatic Apparatus With Round Rotating Platforms**

Often, in machine parts with complex forms, the surfaces to be quenched are in different planes, and such machine parts cannot be treated with completely automatic equipment.

Instead of an automatic apparatus which is adjustable for quenching various machine parts with different shapes it is more economical to use small semi-automatic apparatus for quenching different portions. The time needed to change inductors and adjust a single automatic apparatus would, in the long run, be more expensive than a series of small apparatus specially adapted to each part.

We constructed three machines for quenching three separate surfaces of transmission forks. These machines have round tables which rotate intermittently (Fig. 9). The forks are placed on the table and pass through the inductor and quenching spray as the table rotates. Two forks are treated simultaneously.

All three machines are connected to a high-frequency transformer (PVV 100/8000). When all three machines are operated simultaneously 100 forks are treated per hour.

**LITERATURE CITED**

1. S. E. Ryskin, Quenching Equipment [in Russian], Mashgiz (1957).