THE FIRST CONFERENCE OF RUSSIAN METALLURGISTS

SURFACE AND DEEP AND SURFACE HARDENING OF STEEL AS A MEANS OF STRENGTHENING OF CRITICAL MACHINE
PARTS AND ECONOMY IN MATERIAL RESOURCES

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In recent years in development of metallurgy and heat treat technology two, at first, glance, contradictory tendencies have appeared ever more clearly:

1) the development of designs of machines and mechanisms frequently requires from metals higher than obtained at present properties of static strength and fatigue resistance, resistance of contact spalling (pitting), wear resistance, and the capability of operation at low temperatures and in many cases it is desirable to reduce the weight of parts;

2) use of new materials and production operations must be economically advantageous and satisfy conditions of protection of the environment (use of toxic substances and those harmful to man and the nature of production wastes is eliminated).

Surface heat treatment with use of induction heating makes it possible to successfully solve the above problems for a broad range of heavily loaded critical machine parts.

The possibilities of induction heating are realized most desirably and fully in so-called deep and surface induction hardening of steels with controlled hardenability [1, 2].

Surface induction hardening has been used in industrially developed countries for more than 50 years. However, in its initial form the following disadvantages were characteristic:

only a thin surface layer was hardened while the properties of the part core remained unchanged (did not increase) during heat treatment, which limited the attainable level of strength properties of parts;

the method used did not make it possible to treat to a high hardness (≥ 60 HRC) without the danger of appearance of cracks in steel with a carbon content of more than 0.50-0.55% and therefore induction surface hardening was used primarily for steels with 0.4-0.5% C, which did not provide the possibility of obtaining a high level of wear resistance and contact strength of heavily loaded parts;

many parts of complex form such as gears, spiders, and parts of complex rolling bearings were not able to be surface hardened as the result of the impossibility of providing them with rapid (for 10-15 sec) uniform surface heating;

to prevent formation of cracks in surface hardening special quenchants, soluble polymers such as osmanil, aquaplast, and others, were used, which required additional costs for purchase of them and complicated production.

A new variation of induction hardening, deep and surface hardening, makes it possible to eliminate these disadvantages and with high technical and economic benefits to realize the following advantages:

a single operation provides surface hardening of parts to a specified depth and maximum hardness, the level of which depends upon carbon content (for steels with ~0.4% C 60 HRC and with ≥0.6% C 65-67 HRC) and hardening of the core to a hardness of 30-40 HRC and in the surface layers of the part compressive stresses (up to 600-800 N/mm²) significantly exceeding their fatigue resistance are created;

for critical heavily loaded machine parts a record high combination of properties, static strength, fatigue resistance, resistance to contact spalling (pitting), and also a reserve of ductility at equal hardness exceeding similar properties of alloy steels after widely used hardening processes such as carburizing, hardening and tempering, and thermomechanical treatment, is reached, which makes it possible to reduce by 20-30% the weight of some parts;


Fig. 1. Macrostructure of gears with \( m = 6 \text{ mm} \) of 45 (a) and 58 (55PP) (b) steels after deep and surface hardening.

![Macrostructure of gears](image)

Fig. 2. Relationship of the brittle fracture resistance in bending (\( P \) is the failure load) to austenitic grain size of a 6 mm diam. 45 steel specimen after heating at rates of 10-100 °C/sec, hardening, and low-temperature tempering.

Fig. 3. Characteristic curves of residual stresses in the cross section of surface hardened parts (\( l \) is distance from the surface): a) 30-mm-diameter 45 steel rod; 1) without tempering; 2) tempered at 180°C; b) 14 mm thick ShKh4 railroad car axle bearing ring.

In production of parts to be deep and surface hardened to obtain the optimum service properties it is necessary to use economically alloyed or special carbon steels developed for this method with controlled hardenability and carbon content ranges of 0.2-0.3%, 0.4-0.5%, 0.55-0.65%, 0.95-1.05%, and 1.1-1.2% and selection of the carbon content depends upon the shape of the part and its operating conditions;