INDUCTION HARDENING

Induction is heating is the most widely used heat treatment for round bar when productivity and repeatability are critical.
Steel, which is a good conductor of electricity and has ferromagnetic or paramagnetic qualities, is heated by the Joule effect (in which a conductor through which a current is flowing dissipates energy as heat proportionally to the duration and power of the current itself).
The intensity of the magnetic field generated by the induction coils falls of as the square of the distance between the coil and the surface of the material, and this is the critical parameter for the transfer of energy.
The amount of heat induced is proportional to the duration and power of the induction circuit.
Electromagnetic induction thus enables us to bring steel to a high temperature and thus create an austenitic structure.
Due to the skin effect of AC current, the thickness of the heated layer varies with the frequency of the current and the thermal conductivity of the conductor. High thermal conductivity thus enables us to heat the material to a greater depth.

Formula for calculating the penetration of the induced current P in mm

$$P = 50\sqrt{\frac{e}{u\,f}}$$

e = resistivity of the steel
u = magnetic permeability of the steel
f = output frequency of generator

In industrial applications one uses low (< 5 kHz), medium (5 to 30 kHz) and high frequency generators (200 kHz).
The penetration is inversely proportional to the square root of the frequency. E.g.: low frequencies penetrate more deeply.
The part is heated by sliding it lengthwise through a series of coils, thus heating it progressively.
It is then quenched in water or a water/polymer emulsion, usually sprayed onto the part passing through as it rotates around its length.
The size of the part is also critical to the process.
Currently, good results can be obtained with bar thicknesses from 6 to 180 mm.
The last step in the process is induction tempering, using a similar heating process to austenization, followed by slow air cooling on racks.
This process is widely used, also for surface hardening of steel, where the hardening is limited to a few mm depth of the round bar's circumference and tempering is replaced by stress relieving at 200 - 300 °C.

Note: the raw material must be annealed to prevent breakages during hardening, and then rolled to keep straightness to within 2 mm/m when the part is conveyed while rotating axially.

Passage through the heating coil.

Induction heat treatment at Tre Valli Acciai division of the Lucefin Group.