HEAT TREATMENTS

Normalizing; normalizing consists in heating to a temperature above AC3 for a time sufficient to allow complete austenization of the material followed by cooling in still or forced air. This process is usually carried out on hot work rough parts in order to obtain a finer grain so that the steel is in the best conditions for subsequent heat treatments.
Annealing ; the purpose of annealing is to soften the steel so that it is suitable for mechanical and/or plastic machining, to eliminate residual stresses and to eliminate the effects of plastic deformation, of welding or of a previous heat treatment.
The various annealing cycles must be selected according to the hardness and structures required for a specific type of machining.
The most frequently used cycles are as follows:

- **Sub-critical annealing**: The part is heated below the transformation temperature point AC1, held at this temperature for an appropriate length of time and then cooled as required (in free air too)This treatment, which is the most widely used for structural steels in view of its cost-effectiveness, is carried out both to soften the steel and also to eliminate residual stresses and plastic deformation effects. The structure obtained consists mainly of very fine spheroid perlitic shapes but not always clearly defined.This class included the so-called workability annealing, normally carried out at a temperature of around 50° C below point AC1 in order to soften the material without any substantial modifications to its structure.
- **Isothermal annealing:** The part is heated to a suitable temperature in the range AC1+AC3 or above AC3,followed by fairly fast cooling to an appropriate temperature of the perlitic range (atwhich the steel remains for a sufficient time) to complete transformation .After that final cooling to room temperature, can be quickly performed with a considerable saving of time. This structural state is particularly suitable to obtain considerable improvements in workability of the tool in the case of particularly difficult machining.

Hardening ; the hardening treatment includes austenitizing heating followed by sufficient fast cooling to a temperature below Ms to permit transformation into martensite, a very hard brittle structure. For perfect (or ideal or complete) hardening, that is to say with a 100% martensitic structure, the cooling rate must be higher than the typical critical rate for each steel.
Carbon steels are characterized by a very high critical hardening rate; this rate is reduced because of the more or less marked presence of alloying elements, according to their percentages and nature.
The most suitable quenching medium, that is to say water, oil or air, must be selected according to the type of steel and the dimensions of the parts to be hardened.
Tempering: When hardened, steel is defined by a high level of hardness and low toughness properties. A subsequent treatment is therefore required to produce a more or less deep modification of the martensitic hardening structure, eliminating its stresses and brittleness.
This treatment, known as tempering, includes heating to a temperature below AC1, holding at this temperature for a certain time and lastly, tempering must be carried out immediately after hardening to avoid the danger of cracks due to the high level stresses present in hardened parts. The tempering temperature must be selected in order to obtain the best compromise between hardness and toughness. It is know that, as temperature increases, there is a gradual increase in toughness, elongation and contraction and correspondingly, a reduction in hardness, in tensile strength and yield.
When the tempering temperature is around 600° C, the resulting treatment is called hardening and tempering, which makes it possible to endow the steel with a good compromise between toughness and strength. The resulting structure in known as sorbate.
Stress relieving ; Stress relieving , which consists in heating to temperatures below 250° C, is used for casehardening or air- hardening steels in order to restrict and possibly eliminate residual hardening stresses while maintaining high level hardness. In this way, there are no appreciable modifications to the structure. Stress relieving is also carried out on parts that are particularly stressed after machining. In this case, the aim is to restore the previous mechanical properties in particular as regards elasticity (yield point) and toughness .
Austempering: Austempering consists in a single treatment in which tempering can usually be omitted and has the advantage of not causing warpage and stress cracks as may happen in the case of conventional hardening. One of the main drawbacks of this treatment is its limited penetration , which does not exceed 30 mm for the UNI 39 NiCrMo3 type and more than 40mm for the UNI 40NiCrMo7 type.
Martempering: The purpose of this treatment is to eliminate the drawbacks of conventional hardening which generates dangerous internal stresses during fast quenching in hardening baths; these stresses may result in rejects due to cracks and distortions, in particular in the case of intricately-shaped parts with considerable variations in section.
Martempering is usually followed by tempering so that required properties are reached.
Solution annealing: (Hardening of austenitic steels)- This treatment , also known as "solution heat treatment" or hyperhardening has only the cooling rate temperature in common with hardening but not the hardening effects that in causes in hardenable steels; it should be remembered that the transformation points of the so-called "austenitic steels"

are below room temperature. This process consist by heating the part in the range of 1000 and 1100° C and hold at this temperature for a sufficient time to eliminate the structural alterations (caused by previous machining). A complete as possible "solubilization" of the austenite carbides can also be obtained; subsequent cooling, in air or water, must be fast enough to prevent precipitation of the carbides, usually occurring in slow cooling rates (in the range between approx. 450 and 850° C) Maximum softening of austenitic stainless steels is achieved with this treatment.

Surface hardening treatments

Surface hardening (or also throughout the section), with induction heating. This treatment requires the use of particular equipment, consisting basically of a coil through which high frequency current passes, thus generating a magnetic field. Inserting the steel part inside this coil, an induced current is generated, which due to the —Joule effect, heats the steel very quickly above AC3. The hardening water can be supplied by the same copper coil acting as inductor (or by using separate pipes), which must however always be close to the inductor. With very high frequencies (700.000-600.000 Hz) heating affects a very thin surface layer but higher heating depths con be obtained reducing the frequency (2.000-20.000 Hz).

Whit even lower frequencies, a complete heating to the core is obtained and this particular feature is used in pass-through type hardening systems (and subsequent tempering)with induction heating.

Casehardening: the purpose of "carburizing" or more simply "casehardening" is to obtain a product that, after subsequent heat treatments, is characterized by a very hard, wear resistant surface layer and also a tough core. It consists in surface carburizing of low carbon steels by holding these for long periods at high temperature in a carbonaceous material.

Nitriding: this is a surface hardening treatment similar to that outlined above except that, in this case, nitrogen is absorbed. This operation consists in holding the parts for a long period at approx. 500° C in media able to give off this element. Unlike casehardening, it is carried out on already hardened and tempered material and does not require subsequent treatments.

Steels for nitriding are hardening and tempering steels containing special elements (aluminium, chromium, molybdenum, vanadium);surface hardening is due to formation of very hard azides (of aluminium, chromium, etc.) whereas the molybdenum must be present in order to reduce temper embrittlement that would otherwise affect the steel during nitriding.

Like casehardening and, in general, all surface hardening processes, nitriding is intended to increase endurance strength too in addition to wear strength.

Remember that:

- Surface hardening through nitriding is due to the formation of aluminium-chromium-vanadium and iron azides in the steel and is therefore the result of a chemical reaction and not of a structural transformation of the steels, through heat treatment, as happens in all the other surface hardening processes (casehardening. Surface hardening. etc.)

HEAT TREATMENTS / ANNEALING, CEMENTATION, TEMPERING, INDUCTION HARDENING,NITRIDING.

SURFACE TREATMENT	SURFACE HARDNESS	WEAR RESISTANCE	CONTACTLOAD CHARACTERISTICS	FATIGUE RESISTANCE TROUGHT FLEXION	SEIZURE RESISTANCE	DISTORTION AND DIMENSIONAL CONTROL	HARDENING CRACKS TENDENCY
CASEHARDENING	High	High	Good	Good	Good	Sufficient	Minimal
CARBONITRIDING	High	High	Reasonable	Good	Good	Good	Minimal
NITRIDING	Very High	Very High	Reasonable	Good	Excellent	Excellent	Minimal
INDUCTION HEATING	High	High	Good	Good	Reasonable	Reasonable	Low
SURFACE HARDENING BY FLAME HEATING	High	High	Good	Good	Reasonable	Reasonable	Low
LASER HARDENING	High	High	Good	Good	Reasonable	Reasonable	Low