Carburising
Temperature of carburizing
Hardness and strength of carbon steels

Martensite

Carburising steels
Quantity of residual austenite

Over eutectoid strongly grows

By hypereutectoid steels many austenite hardness decreases risk of overcarburising
Carburising speed

- 950 °C
- 925 °C
- 900 °C
- 870 °C

Time of carburising [hour]

Carburising depth [mm]
Results of carburising

Mean hardness 58 to 62 HRc
- the most common method of measuring hardness after hardening.

Depth is usually a few tenths of a millimeter, exceptionally up to 2 mm

Determining the depth of hardening:
- Hardness after quenching is 50 HRc (530 HV)
- The carbon content is above 0.4%

After cementation must be steelhardened and tempered.

Time of carburising is determined from the carburising temperature, depth and type of steel (alloys generally slow diffusion)
Temperature of hardening after carburising

There is no common optimal hardening temperature
Direct hardening - simplest

Core and layer hardened from too high temperature

Carburising temperature

Cheapest
Worst structure
Only for inferior purpose
One-stage hardening – for layer

Layer has optimal properties

Core is coarser and fragile

Compromise between price and quality
Two-stage hardening

Optimální structure and properties of core and layer

Most expensive method
Best mechanic properties

Greater deformation after hardening
Concentration of carbon after carburisation

Direct after carburisation by surface too steep

Therefore often added diffusion rate: temperature is the same, atmosphere without carbon
Carbon concentration after diffusion period

- Hardness by surface less steep - approximately constant
- At the same time increased depth of carburising
Powder carburising

Charcoal and BaCO$_3$ ratio 5 : 1

Must be done in pent-up container.
When heated to the carburizing temperature must be created CO - then the decomposition on the surface of load:

$$2 \text{CO} = \text{CO}_2 + \text{C}.$$ 

Outdated method, but very cheap
Carburising in fluid

Fluid is molten chloride and cyanide of alkali metals

Transporter of carbon into steel surface is group CN, therefore is together diffusion of nitrogen

Rapid method previously relatively frequent, today banned for toxicity of cyanide (KCN - potassium cyanide - LD50 = 0.2 g)

Penetrate the skin!

Intensive development - Search for new, non-toxic bath
Carburising in gas mixture

Carried out at atmospheric pressure, or at low overpressure.

The used gas mixture is in thermodynamic equilibrium.

Used active atmosphere:
endoatmosphere or decomposed methanol

Approximate composition:
**40% nitrogen, 20% hydrogen and 20% CO**
the rest is water vapor and CO₂.

For good carburising necessary regulation the carbon potential of the atmosphere of 0.8 -1%.
Limits for regulation
endoatmosphere - methane + air with 1 % water

workspace
0.8 to 1 % C
870 to 970 °C

black dew points:
from -16 to +1 °C

blue mixing ratio
air : methane
2.38 to 2.44

Green reaction constant:
from 20 to 80

Yellow area
- suitable carburising conditions
Regulation with C probe

Today most common. Indicates direct carbon potential

It uses the properties ceramics ZrO$_2$ as solid electrolyte.
- Ceramics can go through oxygen ions.
Carburising in liquid hydrocarbon

Dripping with kerosene, benzene or a mixture of acetone, turpentine and alcohol. Consumption 0.3 to 5 l/h.

Vaporizes and decomposes on the hot plate. It is not thermodynamic equilibrium - there is no C potential.

Furnace with lid on top - **monocarb**. It is required fan for uniform distribution of products of decomposition. Seal of cover with molten metal.

Very limited controlability.
Carburising in gaseous hydrocarbon

The tendency at atmospheric pressure and higher temperature (without oxygen) to produce soot.

To avoid this, there must be no thermodynamic equilibrium - only the first stage of decomposition.

Soot formation is controlled by transparency of the atmosphere, propane is supplied in pulses.

Other option - by the presence of soot in the furnace is admitted air - soot burn.
Dilution of hydrocarbon

- The process Carbopulse of company LINDE
  - a mixture of nitrogen and propane
  - propane has a very low partial pressure
  - by that is suppressed soot formation.

- Alternatively, it is possible to eliminate soot gently bringing the air (oxygen).

- We can also reduce the total pressure of the atmosphere
  - Vacuum carburizing.
Principle of vacuum carburising

- Atmosphere of pure methane, propane, acetylene.

- To prevent sooting is necessary to reduce the pressure.

- To ensure sufficient supply of carbon, generally raise the temperature of carburising - up to 1050 °C.

Graph for methane
Properties of vacuum carburising

Absent oxygen or other oxidant - maintain the quality oxide-free surface

The vacuum carburizing is faster than in the classical gas - higher temperature

Reduction of deformations and internal stresses

The method is very ecological - wasteless

Low energy consumption and hydrocarbon

Disadvantage - it is necessary to prevent the occurrence of soot

Control worse - no balance

For less then 1 mm in depth vacuum carburizing less effective - the influence of the evacuation period.
Pulse vacuum carburising

**Method of firma HAYES**

Typically 5-10 pulses after 3-5 minutes. Between them the same diffusion time

**Control only with number and length of pulses.**
Control depending on increasing of pressure

When is methane fully decomposed\[ \text{CH}_4 = \text{C} + 2 \text{H}_2 \] must be doubled pressure - the pressure increase is an indicator of reaction process. During its growth to limit the sooting is the atmosphere restored by filling of new methane.
Control depending on transparency of atmosphere (Ibsen)

Soot decline transparency of atmosphere.

Then always drains old methane and is filled new.
Mikrostructure of carburised layer

The depth of carburising can be roughly assessed by metallographic structure.

Hypereutectoid area is undesirable - the possibility of grid of cementite, increased amount of residual austenite.
Example of right carburised product

Must be uniformly deep carburizing layer with gradual transition into the kernel.

Because carburising increases corrosion, it is possible to assess depth of cementation also by corrosion on the cut of components.