**Nitriding:**

- It is a process of introducing \( N_2 \) into a solid Ferrous alloy by holding at a suitable Temp. \( T^o \) below \( A_1 \) \( [500 – 590 \, ^\circ C] \), for Ferritic Steels for enough time \( (40 – 100 \, \text{hour}) \) in contact with nitrogenous material usually \( \text{NH}_3 \) or another Cyanide of appropriate composition:

\[
\text{NH}_3 \rightarrow 3 \, \text{H} + (N)
\]

- Quenching is not requested to produce a Hard Case in this process.

**Advantages:**
- No Crack.
- high hardness \( [H_v \, (\text{Vickers hardness}) = 1150] \).
- improve corrosion resistance.
- improve Fatigue resistance.
- hardness is un-affected by heating below \( (50 \, ^\circ f) \).
- clean \( \text{no Carbon produced} \).

**Disadvantages:**
- Cost.
- long cycle required.
- technical control required.
- loss hardness if reheated for enough time.
Cyaniding:

- It is a process of introducing \((C + N_2)\) into a solid ferrous alloy by holding above \(A_1\) \((1400-1600\, ^\circ F)\), in contact with molten Cyanide of suitable composition \((30\% \text{ NaCN} + 40\% \text{ Na}_2\text{CO}_3 + 30\% \text{ NaCl})\) or by use gas atmosphere [Carbonitriding \((\text{gas contains } (C + N_2))\).

- The Carbon percent content in the Case is lower than in Carburizing ranging from \((0.5 - 0.8)\)% \(C\) with \(0.5\% N_2\).

- Molten Cyanide decomposes in the presence of Air as follows:

\[
\begin{align*}
\text{NaCN} + O_2 & \rightarrow 2 \text{NaNCO} \\
4 \text{NaNCO} & \rightarrow \text{Na}_2\text{CO}_3 + 2 \text{NaCN} + \text{CO} + 2 \text{N}
\end{align*}
\]

Flame Hardening:

- It is suitable for Steel which is \((0.3 - 0.6)\)% \(C\).

- Don’t change the chemical composition of the Steel.

- Shallow hardening method.

- Selected areas of the surface of Steel are heated into \((\gamma)\) range and then quenched to form \((M)\).

- Heat may be applied by a single Oxy- acetylene torch [see fig. (22) below].

- Depth of the hardened zone may be controlled by:
  - adjustment of flame intensity.
  - heating time.
  - speed of travel.

- Methods used for flame hardening are:
  - stationary \((\text{both torch + work are stationary})\).
  - progressive \([\text{torch moves over a stationary work piece (W/P)}]\).
  - spinning \((\text{torch is stationary while (W/P) rotating})\).
  - progressive spinning \((\text{torch moves over a rotating (W/P)})\).
Advantages of Flame hardening:
- adaptability.
- portability.
- ability to treat component after surface finishes since there is little (Scaling, Distortion & Decarburizing).

Disadvantages of Flame hardening:
- possibility of overheating & thus damage the parts.
- difficulty in producing hardened zone < 1/16” in depth.

Induction hardening:

It is similar to Flame Hardening except heating is produced by currents induced in a metal placed in a rapidly changing magnetic field [see fig. (23) below].

When high frequency alternating currents passes through the work coil, high frequency magnetic field induces high frequency eddy currents and hysteresis currents in the metal piece.

Heating results from the resistance of the metal piece to the passage of these currents.

Advantages:
- min. case depth with max. surface hardness.
- ability to fit the equipment directly in the production line.
- it is done automatically with unskilled labors.

Disadvantages:
- Cost.

Part that have been produced by induction – hardening are (piston rods, pump shaft, spur gear & cams).
Fig. (23): Various methods of Induction hardening