Basics of (Gas-) Nitrocarburizing
and how to steer and control the process

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• Basics of (gas-) nitriding / (gas-) nitrocarburizing

• Standard and controlled processes

• Oxinitriding / Oxinitrocarburizing processes

• Postoxidation processes

• Processes with additional hydrocarbons

• Furnace technology
Basics of (gas-) nitriding / (gas-) nitrocarburizing
Basics of (gas-) nitriding / (gas-) nitrocarburizing

**Nitriding layer**

- Pores
- Oxide
- Compound layer

**Properties of the Nitriding layer**

- Chemical resistance
- Adhesion properties
- Hardness
- Toughness
- Strength
- Inherent compressive stress
- Thermal resistance

**modified useful Properties**

- Corrosion resistance
- Wear resistance concerning abrasion, deforming, bonding, and galling
- Flaking, chunking and cracking
- Resistance against surface fatigue
- Vibration stability
- Dimensional stability
- Thermal wear
- Resistance against thermical fatigue

**Diffusion layer**

- **OS** = Oxide layer
- **VS** = Compound layer

**Formation especially by the alloying elements Al and Cr**

**Base material**

**Special nitrides**

- Absorption of lubrication solvents
- Resistance against thermical fatigue

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# Reaction Agents for gas nitriding and gas nitrocarburizing

<table>
<thead>
<tr>
<th>Diffusion Element</th>
<th>Process</th>
<th>Reaction Agents</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>Nitriding</td>
<td>NH₃, NH₃ &amp; N₂, NH₃ &amp; H₂, NH₃ &amp; N₂ &amp; H₂</td>
</tr>
<tr>
<td>N, C,</td>
<td>Nitrocarburizing</td>
<td>NH₃ &amp; Endothermic gas, NH₃ &amp; CO₂ &amp; (N₂), NH₃ &amp; CₘHₙ, &amp; (N₂)</td>
</tr>
</tbody>
</table>
Reactions during (gas-) nitriding

Nitriding atmosphere

Nitriding atmosphere

Diffusion-boundary layer

Phase border

gas
metal

Basics of (gas-) nitriding / (gas-) nitrocarburizing
Reactions during (gas-) nitrocarburizing

Basics of (gas-) nitriding / (gas-) nitrocarburizing
Background of Nitrocarburizing

Temperature range normally used for Nitriding or Nitrocarburizing processes.
Nitriding potential and Nitriding layer structure

Normally used range of temperature for the gas nitriding or nitrocarburizing (480°C – 590°C)
Standard processes
Standard process for nitriding

- **Heating**: Heat treatment temperature (°C)
  - 350°C - 400°C
  - 480°C - 550°C

- **Evacuating**: Evacuating phase

- **Filling**: Filling phase
  - Air
  - N₂
  - NH₃
  - CO₂
  - CH₄
  - H₂O
  - **Filling**: 15 m³/h N₂

- **Nitriding**: Up to 50% of the total gasing (small amount) (approx. ___ m³/h)
  - Up to 100% of the total gasing (big amount) (approx. ___ m³/h)

- **Cooling**: < 100°C (150°C) depending on the load

- **Pressure**:
  - ca. 1020 mbar
  - < 40 mbar

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Standard process for nitrocarburizing

- **Evacuation**
- **Filling**
- **Heating**
- **Nitrocarburising**
- **Cooling**

- **Filling**: 15 m³/h N₂
- **Purging big amount of**: __ m³/h N₂

- **Heat treatment temperature [°C]**
  - Room temperature
  - 350°C - 400°C
  - 550°C - 590°C

- **Pressure**
  - ca. 1020 mbar
  - < 40 mbar
  - ca. 1020 mbar
  - < 40 mbar

- **Approximations**
  - 45% of the total gasing (small amount)
  - 50% of the total gasing (small amount)
  - 5% of the total gasing

- **Note**: Cooling depends on the load.
Standard processes

Standard process for nitrocarburizing

- Heating: 550°C - 590°C
- Cooling: < 100°C (150°C) depending on the load

- Nitrocarburizing "Nikotrieren"

- Heating system active
- Cooling package active

- Purging with big amount of Endogas
- Air
- N₂
- NH₃

- approx. 50% of the total gasing (small amount)
- approx. __ m³/h
controlled processes
Benefits of $K_N$ controlled nitrocarburizing

Goals:
- Controlled layer structure generation
- Reproducible layer structure and thickness
- Minimal process duration

Requirements:
- Measurement device for the continuous monitoring of an atmospheric component (e.g. $H_2$)
- Continuous monitoring of the input gases
- Atmosphere and Nitriding potential - Algorithm
- Cracked ammonia or pure hydrogen for the reduction of the nitriding potential
- Automatic gas flow controller
Theoretic Background of the Nitriding Potential

\[
NH_3 \rightarrow [N] + \frac{3}{2}H_2
\]

nitriding reaction

\[
NH_3 \rightarrow \frac{1}{2}N_2 + \frac{3}{2}H_2
\]

nitriding potential

\[
K_N = \frac{p(NH_3)}{p(H_2)^{3/2}}
\]
Hydrogen sensors

For documentation and control of nitriding- and nitrocarburizing processes
CN panel for $K_N$ controlled nitrocarburizing

controlled processes

- furnace atmosphere
- hydrogen-probe
- temperature
- mV, H$_2$O, $K_0,T$
- Nitro-Prof $^\circledR$
- mV set point

- CO$_2$
- N$_2$
- NH$_3$

- NH$_3$ - Cracker
- MFC
- MFC
- MFC
- MFC

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controlled processes

process for $K_N$ controlled nitrocarburizing

- Pre-oxidation
- Evacuating
- Filling
- Heating
- Conditioning
- Nitrocarburising
- Post-oxidation
- Cooling

- Big amount air approx. ___ m³/h
- Controlled by Nitro-Prof
- approx. 45% of the gasing (approx. ___ m³/h)
- approx. 50% of the gasing (approx. ___ m³/h)
- ca. 0.5 m³/h $NH_3$
- ca. ___ l/h $H_2O$
- ca. 1020 mbar
- ca. 1020 mbar
- Filling: 15 m³/h $N_2$
- Basic und controlled amount calculated by Nitro-Prof always with the same ratio of 50% $NH_3$, 45% $N_2$, 5% $CO_2$
- Purging big amount of: ___ m³/h $N_2$
- < 40 mbar
- < 40 mbar

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controlled processes

Process printout $K_N$ controlled nitrocarburizing

Furnace temperature

<table>
<thead>
<tr>
<th>Temperature [° C] and gasing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydrogen ($H_2$)</td>
</tr>
<tr>
<td>Nitrogen ($N_2$)</td>
</tr>
<tr>
<td>Ammonia ($NH_3$)</td>
</tr>
<tr>
<td>Carbondioxid ($CO_2$)</td>
</tr>
</tbody>
</table>

Nitriding activity ($K_N$ - number)

$K_N$ - number
Oxinitriding / Oxinitrocarburizing processes
Influences on the reaction kinetics

**Inhibition, due to:**

- Fabrication Residues (i.e., cooling oil, grease)
- Detergent Residues
- Surface strengthening
- Surface smoothness
- Passive oxide layer (chromium oxide)

**Process sequence for activation:**

- Perfect Cleaning and Pre-oxidation
- Oxinitriding or Oxinitrocarburising
Oxinitriding / oxinitrocarburizing processes

Reaction kinetics improvement - Oxinitrocarburizing

- Purge phase e.g. N₂
- Heating phase in NH₃
- Heating & Holding in NH₃ / Oxidation agent
- Holding in NH₃ / carburizing agent
- Holding Phase (with K_N-Control)
- Purge phase e.g. N₂

- X5CrNiMo17-22-2
- X40CrMoV5-1

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Modell for the conversion of passive layers

\[
\text{NH}_3 \quad [\text{NH}_3 + \text{N} + \text{H}]
\]

Phase 1

\[\text{RT} - 400^\circ \text{C}\]

Atmosphere Formation Phase

Explanation:

Cr$_2$O$_3$  Fe$_3$O$_4$  Fe  Cr  CrN  Fe$_x$N
Oxinitriding / oxinitrocarburizing processes

Modell for the conversion of passive layers

\[ \text{NH}_3 + \text{Oxidation medium} \rightarrow [\text{NH}_3 + \text{N} + \text{H} + \text{O}] \]

Phase 2

\[ 400 - 580^\circ \text{C} \]

Oxinitriding Phase

Explanation:

\[ \text{Cr}_2\text{O}_3 \quad \text{Fe}_3\text{O}_4 \quad \text{Fe} \quad \text{Cr} \quad \text{CrN} \quad \text{Fe}_x\text{N} \]
Oxinitriding / oxinitrocarburizing processes

Modell for the conversion of passive layers

\[ \text{NH}_3 + \text{Carburising medium} \quad [\text{NH}_3 + \text{N} + \text{H} + \text{C}] \]

Phase 3

Explanation:

\[ \text{Cr}_2\text{O}_3 \quad \text{Fe}_3\text{O}_4 \quad \text{Fe} \quad \text{Cr} \quad \text{CrN} \quad \text{Fe}_x\text{N} \]

580° C

Nitrocarburising / Reduction Phase
Oxinitriding / oxinitrocarburizing processes

Process for oxinitriding

- Heating
- Oxinitriding
- Nitriding
- Cooling

Heat treatment temperature [°C]

- Room temperature
- 500°C
- ca. 350°C - 400°C
- 480°C - 550°C

Pressure

- ca. 1020 mbar
- < 40 mbar

Filling:
- 15 m³/h N₂

Gasing:
- up to 50% of the gasing (small amount)
- approx. _ m³/h
- up to 100% of the gasing (big amount)
- approx. _ m³/h

Purging big amount of:
- _ m³/h N₂

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Oxinitriding / oxinitrocarburizing processes

Process for oxinitrocarburizing

- **Heat treatment temperature [°C]**
  - ca. 500°C
  - ca. 350°C - 400°C
- **Room temperature**
- ** Heating phase (550°C - 590°C)**
- **Oxinitrocarburising**
- **Nitrocarburising**
- **Cooling**
  - ≤ 100 °C (150 °C) depending on the load

- **Pressure**
  - ca. 1020 mbar
  - ca. 1020 mbar
- **Filling**
  - 15 m³/h N₂
- **Purging big amount of**
  - _m³/h N₂
- **Gas composition**
  - Luft
  - N₂
  - NH₃
  - CO
  - H₂O

Approximations:
- approx. 45% of the total gasing (small amount)
  - (approx. _ m³/h)
- approx. 50% of the total gasing (small amount)
  - (approx. _ m³/h)
- approx. 5% of the total gasing
  - (approx. _ m³/h)
- ca. _ l/h
- ca. _ Liter/h

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Oxinitriding / oxinitrocarburizing processes

Process for oxinitrocarburizing

- Heating
  - Air
  - N₂: Purging big amount of: \( \text{__ m³/h} N₂ \)
  - NH₃: approx. 50% of the total gasing (small amount)
  - CO: approx. 5% of the total gasing

- Oxinitrocarburising
  - up to small amount air approx. \( \text{__ m³/h} \)
  - approx. 45% of the total gasing (small amount)

- Nitrocarburising
  - Big amount air approx. \( \text{__ m³/h} \)
  - approx. \( \text{__ m³/h} \)

- Cooling
  - < 100 °C (150°C) depending on the load
  - Cooling package active

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(gas-) nitrocarburizing and postoxidation
Basics of nitrocarburizing and postoxidation

Benefits due to postoxidation

By running a postoxidation after a normal (gas-) nitriding- or nitrocarburizing process an iron oxide layer will be formed directly on top of the compound layer. This iron oxide layer has to consist of magnetite (Fe₃O₄) and should have a thickness of 1-3 µm.

Benefits of the magnetite layer:

• corrosion resistance: Due chemical composition and the compact design of Fe₃O₄ – oxide layer no oxygen can diffuse into the material and therefore no further corrosion can take place.

• optical effect: By running a postoxidation process (Fe₃O₄ – formation) the surface of the part will become a decorative black color. In some cases / for some customers this black color is more appreciated than the grey color you will get after nitriding or nitrocarburizing.

• wear resistance: The oxide layer will always contain a smaller or greater amount of pores and lubricants like oil can get into the oxide layer. This will can cause a higher lubrication effect and therefore a smaller amount of abrasive wear.
Basics of nitrocarburizing and postoxidation

Nitriding layer

Properties of the Nitriding layer
- chemical resistance
- adhesion properties
- Pores → absorption of lubrication solvents

modified useful Properties
- corrosion resistance
- wear resistance concerning abrasion, deforming, bonding and galling
- flaking, chunking and cracking
- Resistance against surface fatigue
- vibration stability
- dimensional stability
- thermal wear
- Resistance against thermical fatigue

postoxidation

 Diffusion layer

Oxide layer

Compound layer

* OS = Oxide layer
** VS = Compound layer

special nitrides
Formation especially by the alloying elements Al and Cr

base material

pores

hardness

strength

inherent compressive stress

thermal resistance

vibration stability

dimensional stability

thermal wear

Resistances against surface fatigue

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(Gas-) Nitrocarburizing with postoxidation

- Oxide layer
- Compound layer
- Base material
Basics of nitrocarburizing and postoxidation

Different types of iron oxide

During the oxidation of iron (Fe) three different types of iron oxide can be formed depending on the oxidation conditions like temperature and oxygen potential:

• haematite (Fe₂O₃):
  This red iron oxide can be formed at room temperature and 'normal' ambient atmosphere. Normally this iron oxide is not magnetic. If in general someone talks about 'the corrosion of iron or steel' normally he is talking about haematite.

• magnetite (Fe₃O₄):
  This black iron oxide can also be formed at room temperature, but therefore special atmospheres are necessary. Normally this iron oxide is formed at postoxidation temperatures of 450 ºC up to 520 ºC. Normally this iron oxide is Ferro magnetic. Only this iron oxide creates a corrosion protective layer.

• wustite (FeO):
  This black iron oxide is stable in a temperature range of T> 560 ºC, additionally also here specific atmosphere condition are necessary.
Basics of nitrocarburizing and postoxidation

Formation of different iron oxides

Temperature [°C]

Temperature [°K]

Oxygen potential [mV]

after IWT Bremen

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## Basics of nitrocarburizing and postoxidation

### Reaction agents for postoxidation

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</tr>
<tr>
<td>N, C, O</td>
<td>Nitrocarburizing</td>
<td>NH₃ &amp; Endothermic gas, NH₃ &amp; CO₂ &amp; (N₂), NH₃ &amp; CₘHₙ, &amp; (N₂)</td>
</tr>
<tr>
<td>O</td>
<td>Postoxidation</td>
<td>demineralized water (H₂O), air (N₂/O₂), laughing gas (N₂O)</td>
</tr>
</tbody>
</table>
Standard process for nitrocarburizing and postoxidation
Standard process for nitrocarburizing and postoxidation

- Pre-oxidation
- Purge
- Heating
- Nitriding
- Post-oxidation
- Cooling

Heat treatment temperature [°C]

- Room temperature
- 300°C - 400°C
- 480°C - 530°C
- 450°C - 520°C

Time [min]

- 15 min
- 45 minutes
- 5 times furnace volume

Gases:
- Air
- N₂
- NH₃
- Endogas

Flow rates:
- Big amount air approx. m³/h
- Big amount air approx. m³/h
- Purging big amount of: m³/h N₂
- Up to 50% of the gasing (small amount) approx. m³/h
- Up to 100% of the gasing (big amount) approx. m³/h

Cooling package active

Heating system active

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controlled postoxidation processes
controlled postoxidation processes

Why controlled Post Oxidation??

The amount of oxygen, which is needed for the process, will be different, depending on:

• the temperature of the postoxidation
• the surface size of the load

So – for example – a load with a big surface size will need much more oxygen (here for example demineralized water) to reach the same results in the oxide layer thickness as a load with a small surface size. This is similar to the controlled nitriding or nitrocarburizing, where more ammonia is needed the bigger the surface of the load is.

The main reason for a controlled postoxidation process is either the optimised consumption of oxygen and even more important the repeatability of the heat treatment results (independent from the surface size of the load).

Therefore only the optimised mV value is necessary!!

This mV value must be found out by trials for every different part, that should be post oxidated.
Formation areas for the different iron oxides

Postoxidation reaction:

\[ H_2O \rightarrow [O] + H_2 \]

Oxidation activity \( K_O \):

\[ K_O = \frac{p(H_2O)}{p(H_2)} \]
CN panel for nitrocarburizing and controlled postoxidation processes

- Retort furnace
- Lambda-probe exhaust gas
- Temperature
- mV value
- Nitro-Prof \( \text{mV, H}_2\text{O, K}_0, T \)
- mV set point
- CO\(_2\)
- N\(_2\)
- NH\(_3\)
- Water

Controlled postoxidation processes
CN panel for nitrocarburizing and controlled postoxidation processes

- Inlet via internal safety burner
- Fiber insulated or bricked furnace
- Furnace atmosphere
- Oxygen probe
- Temperature
- mV value

- mV, H₂O, K₀, T
- Nitro-Prof®
- mV set point

- CO₂
- N₂
- NH₃
- Air

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Process for nitrocarburizing and controlled postoxidation

- Pre-oxidation
- Heating
- Nitrocarburising
- Conditioning Postoxidation
- Controlled Postoxidation PRONOX
- Cooling

- Big amount air approx. __ m³/h
- N₂
- NH₃
- CO₂
- CH₃
- H₂O

- Filling: 15 m³/h N₂
- approx. 5% of the total gasing (approx. __ m³/h)

- approx. 45% of the total gasing (approx. __ m³/h)

- Control by Nitro-Profil Ammonia and H₂O depending on the mV-Value

- Purging big amount of: __ m³/h N₂

- Filling: 15 m³/h N₂

- ca. 1020 mbar
- ca. 1020 mbar
- ca. 1005 mbar

- < 40 mbar
- ca. 1020 mbar

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Cycle printout of a controlled postoxidation process – test run -

Programmed values for the $\lambda$ – Sensor:
- app. 880 mV
- app. 860 mV

Water ($\text{H}_2\text{O}$)

Ammonia ($\text{NH}_3$)

mV Signal

$\lambda$ - probe
Cycle printout of a controlled postoxidation process – test run -

Programmed values for the $\lambda$ – Sensor: app. 1050 mV
Gas nitrocarburizing and controlled postoxidation with the addition of propane (C₃H₈) of C15

Requirements for best results in corrosion resistance:

- 1 - 3 µm iron oxide layer Fe₃O₄
- min. 8,6 % Nitrogen plus Carbon content
- min. 15 µm ε - compound layer
- Base material
Heat treatment process

1.) nitrocarburizing
   - NC temperature: 580° C
   - NC time: 5 h
   - gasing system: NH₃ & Endogas

2.) cooling down to 450° C
   - gasing system: NH₃ & Endogas

3.) controlled postoxidation
   - postoxidation temp.: 450° C
   - postoxidation time: 75 min
   - gasing system: air & Endogas

4.) cooling down to 150° C

Heat treatment results

Material: C15 ~ 1.0401

Micrographic picture

Concentration profile

Time in salt spry test (Din EN ISO 9227):
456 hours!
# Heat treatment process

1.) nitrocarburizing
   - NC temperature: 580° C
   - NC time: 5,5 h
   - gasing system: NH₃ & N₂ & CO₂

2.) cooling down to 500° C
   - gasing system: NH₃ & N₂ & CO₂

3.) postoxidation
   - postoxidation temp.: 450° C
   - postoxidation time: 75 min
   - gasing system: demineralized water

4.) cooling down to 150° C

---

## Heat treatment results

Material: 42CrMo4 ~ 1.7225

---

### Micrographic picture

---

### Concentration profile

**O, N+C content [vol%]**

---

**Time in salt spry test (Din EN ISO 9227):** 336 hours!
Processes with additional hydrocarbons
Benefits of additional hydrocarbons in NC processes

By using additional hydrocarbons in nitrocarburizing processes, the carbon content in the surface area of the compound layer is increased. This will cause two beneficial effects

• The higher carbon content will increase the formation of ε-nitrides. The ε : γ’ ratio of the compound layer can be increased from 7:1 up to 11:1 and therefore the wear resistance is improved

• The use of hydrocarbons in the last segment of the nitrocarburizing and also in the cooling segment prior to a postoxidation step will increase the N+C content in the top area of the compound layer. A N+C content of 8,6 Vol% or more is beneficial for the corrosion resistance
How to use additional hydrocarbons in NC processes

Due to the fact that the nitrocarburizing temperature is in the range of 560 – 590 °C, the reaction of the hydrocarbons is limited.

In this temperature range propane (C$_3$H$_8$) shows the best results compared to methane/natural gas (CH$_4$) or other hydrocarbons with a higher carbon content regarding the formation of soot during the process.

The amount of propane should not exceed approx. 3-5 Vol% of the total gasing.

By using the gasing system with ammonia (NH$_3$), nitrogen (N$_2$) and carbon dioxide (CO$_2$) the propane can be used in addition to or instead of the carbon dioxide. Also a double step process (first with CO$_2$ and second with C$_3$H$_8$) is possible.
Processes with additional hydrocarbons

Process for nitrocarburizing & postoxidation with propane

Heat treatment temperature [°C]

Room temperature

Pre-oxidation

250°C - 400°C

Evacuation

Back Filling

Heating

Conditioning

controlled process

Nitrocarburizing

450°C - 550°C

Post-oxidation

550°C - 590°C

Cooling

< 100 °C (150°C) depending on the load

Heat treatment temperature [°C]

Heat treatment time [min]

max. 2.0 - 3.0 m³/h air

dissociated ammonia

nitrogen N₂

ammonia NH₃

carbon dioxide CO₂

propane C₃H₈

water H₂O

Pressure

c. 1020 mbar

< 40 mbar

ca. 1020 mbar

ca. 1020 mbar

< 40 mbar

Kₙ⁻ controlled

Kₙ⁻ controlled

Approx. 45% of total gasing

Approx. 50% of total gasing

Optional use

Approx. 5% of total gasing

Approx. 3% of total gasing

Purge: N₂

Back filling: N₂

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Gas nitrocarburizing with the addition of propane (C$_3$H$_8$)  
Increase of wear resistance

CO$_2$ - process  
$\varepsilon : \gamma'$ ratio 4 : 1

CO$_2$ & Propane - process  
$\varepsilon : \gamma'$ ratio 11 : 1
Furnace technology
Furnace technology used for (gas-) nitrocarburizing and postoxidation

**Necessary furnace requirements:**
exact temperature controlling (± 5 °C or better)
Adequate amount of gassing (approx. 3 times of the furnace-volume / h)
intensive gas-circulation

**Normally used furnaces technology:**
Chamber furnace (batch wise treatment)
  - sealed heating chamber
  - scale resisting retort

**Continuously working furnace**
  - pusher type furnace
  - belt furnace
Bricked or fiber insulated chamber furnace

**Advantage:**
- less catalytic ammonia (NH₃) dissociation
- combination of different chambers possible
  (modular furnace construction)

**Specific feature:**
- slow changing of the furnace atmosphere
- **NO** use of demineralized water possible
Sealed retort furnace

**Advantage:**
- Fast change of furnace atmosphere possible
- Evacuation is possible
- Use of demineralized water possible

**Specific feature:**
- Limited lifetime of the retort (catalytic and scaling effects)
Continuous furnace

Advantage:
- automated processes
- complex processes can be run in one furnace
- Vacuum locks

Specific feature:
- Low flexibility because of high production capacity
- High costs for the furnace
Pusher type furnace

Endothermic gas generator
Preoxidation furnace
Load storage
Control cabinet platform

Vacuum lock
Nitrocarburizing
Gas cooling
Vacuum lock
Load storage

Double line pusher type furnace for nitrocarburizing
Thank you for your attention

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Nitrocarburizing reaction

Nitrocarburising atmosphere

Diffusion boundary layer

Phase border Gas Metal

base material

NH₃ / CO

CO(ad) → C(ad) + O(ad) → H₂O

NH₃(ad) → NH₂(ad) → NH(ad) → 3H(ad) + N(ad) → N₂ + H₂

Fe₄N → Fe₂₋₃(N, C)

[N]Fe
Conclusions
Conclusions for postoxidation processes

• creation of a magnetite (Fe$_3$O$_4$) layer with approx. 1 – 3 µm thickness

• Use of a low temperature (approx. 450 – 480 ºC)
  • Influence on the shape and max. value of the N+C-Profile

• for layers with only decorative purposes the oxide layer may have some more pores than layers for corrosion resistant purposes
  • Higher temperatures (up to 520 ºC) can be used – faster process time
Conclusions for the Post Oxidation

Increase of the corrosion resistance due to:

- compound layer thickness of min. 15 µm (mainly consisting of ε nitrides)
- N+C content of > 8.6 Vol% at the top area of the compound layer
- addition of hydrocarbon at the end of the nitrocarburizing
  - Higher max. value of the N+C-Profile
- cooling down to postoxidation temperature under ammonia and hydrocarbon
  - Influence on the shape and max. value of the N+C-Profile
- small difference between end of oxide layer and max. N+C-value
Installation of the oxygen-sensor

- Bricked sealed Quench Furnace
- Pit Furnace
- Fiber insulated furnace

oxygen sensor