The influence of machining on the effects of nitriding

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Background

Defects of nitriding – as results of inappropriate surface preparation

Macroscopic observation (naked eye):

Surfaces after milling and turning

Different case depth of workpieces after same nitriding process

1000 µm

Defects revealed after milling and nitriding

Different surface thickness on the same workpiece
1. Background

Nitriding, surface reactions, surfaces, chemicals & machining

Mikael Fällström, Bodycote

2. Machining - Nitriding

- Raw Material, micro structure, hardness etc
- Surface control before nitriding processes
- Macro observations after nitriding processes
- Defects after machining
- Surface activations before nitriding processes

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Background – Nitriding Processes

\[ a_n = K \frac{p \text{NH}_3}{p \text{H}_2^{3/2}} \]

\[ \text{NH}_3 \rightarrow \text{N} + \frac{3}{2} \text{H}_2 \]

0.4%C steel

5% Cr Hot-Work steel

1% Cr-Mo Steel

Ref. VBC - Handboken
Background – Nitriding Processes

\[
\text{H}_2 + \text{N}_2 \rightarrow \text{NH}_3
\]

- **Desorption**
- **Diffusion**
- **Catalyst surface**
- **Chemisorption**
- **Decomposition**

Gerhard Ertl 2007
Background – Nitriding Processes

\[ \text{Nitride nucleation/} \]
\[ \text{Growth} \]

\[ \text{NH}_3 \text{ Adsorption/} \]
\[ \text{Dissociation} \]

\[ \text{Constant } a_N \]
Contamination Layer >1μm
- Dirt
- Production residue

Adsorption Layer 1-10nm
- C and O, water

Reaction layer 1-10nm
- Oxides

Deformed Boundary Layer >1μm

Base Material
- Hardness
- Microstructure
- Deformation

All processes before Nitriding will contribute.

Ref. Haase
Background – Surfaces

Active Layers

Passive Layers
Background – Surfaces

**Chemical**
- Surface treatment: *Zinc Phosphate*…
- Washing: *Contamination Layer*
- Machining: *Reaction layers, Iron Sulfide*
- Raw Material: *Chemical composition*

**Mechanical**
- Raw material: *micro structure*
- Machining: *plastic deformation*
- Machining: *Stresses*
Background - Chemicals
Background - Mechanical

Ref. VBC/Handboken
Background - Mechanical

Machining Processes

- Turning & Threading
- Grinding
- Milling
- Deep hole Drilling
- Honing
- Polishing

Hazards
- Temperature
- Plastic deformation
- Contamination
- Reaction layers
Background - Mechanical

[Graph showing the relationship between temperature and cutting speed, with regions labeled as: Break-in period, Steady-state wear region, Failure region, Uniform wear rate, Accelerating wear rate, and Rapid initial wear.]
Nitriding is often one of the last process steps when manufacturing a component.

For the nitriding process **not suitable machine** parameters might cause large problems with scrapped or delayed components.

Nitriding requires a careful and professional surface preparation.
The influence of machining on the effects of nitriding

Part 2

Pawel Szulc
Machining types

- Turning and Threading
- Grinding
- Milling
- Deep hole drilling
- Honing
- Polishing
Modern cutting tools coated with many super-hard layers allow you to use very high machining parameters. In addition, they allow for performing standard operations on steels after heat treatment (hardness 30–45HRC - this is their big advantage. At the same time, apart from the benefits, we should know the potential risks to deal with.
Starting material hardness control

Any material intended for machining should have adequate properties to ensure the best parameters during the machining stage.
An additional aspect is the microstructure of the raw material, which has a significant impact on cutting parameters.
Surface inspection before Nitriding

Surface texture
Roughness
## Surface inspection before Nitriding

<table>
<thead>
<tr>
<th>Sample</th>
<th>Ra, before nitriding</th>
<th>Effective case depth@700 HV, (µm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ground</td>
<td>0.13</td>
<td>135</td>
</tr>
<tr>
<td>Polished</td>
<td>0.08</td>
<td>120</td>
</tr>
<tr>
<td>Lapped</td>
<td>0.04</td>
<td>85</td>
</tr>
</tbody>
</table>

**H13 steel**
Surface inspection before Nitriding

Potential differences on the surface of the workpiece

Before

After 4% Nital etching
Surface inspection before Nitriding

Cleanliness and activity

Electrochemical measuring probe
Macro observations after Nitriding

Defects revealed after nitriding - milling affect on workpiece surface hardness.

Surface hardness after milling before nitriding process
340 ÷ 350 HV1

On 3200 parts surface color differences were observed
On 6800 parts, the correct case depth was observed

740 ÷ 900 HV1
800 ÷ 1080 HV1
1080 ÷ 1140 HV1
Macro-micro observations after Nitriding

0,35mm 0,25mm
Macro-micro observations after Nitriding

Surface workpiece interaction with nitrogen during nitriding process
Macro observations after Nitriding

- surface after drilling
- surface after honing
- surface after milling
- surface after hobbing of tooth space
- surface after polishing
Macro observations after Nitriding

Macroscopic inspection has not revealed large differences in surface quality. Only the hardness measurement has shown significant differences in the effects of nitriding.
Macro observations after Nitriding

Machining and surface activation

500 HV10

990 HV10
Defects after machining

Surface preparation affects on the kinetics of nitriding process.

the boundary layer consists of
a) grease or oil film,
b) adsorption and reaction layer,
c) outer boundary layer,
d) transition zone,
e) inner boundary layer,
f) undisturbed metal structure.
Defects after machining
grain deformation
Defects after machining

Surface after drilling
Material: 41CrAlMo7
Batch weight: 1500 kg;
Quantity PCS: 500 pcs.
Defects after machining
Defects after machining

8 µm

2 µm

2 µm

50 µm

60 µm
To minimize problems with different surface quality prior to nitriding it is recommended to perform surface activation.

Known ways of surface activation:
- **chemical** – oxidation, phosphating or etching in solutions of acids
- **mechanical** – sand/grit blasting, vibroabrasive treatment
- **thermo-chemical** during the nitriding process

Improve the nitrogen diffusion rate at the gas-solid interface.
Surface activation before Nitriding process

Mechanical activation

- proper abrasive material selection (grain size)
- blasting parameters (p, t)
- precise cleaning
Surface activation before **nitriding process**

**Nitro-M®**
- Thermo-Chemical process
- Tool-steels
- Passive surfaces
- No impact on surface roughness
- Normal Nitrocarburising characteristics;
  *Compound layer, hardness, nitriding depth etc*

50µm
Surface activation before nitriding process

Pre-Oxidation

Effect of pre-oxidation on nitrocarburising results. Nitrocarburising 580°C 45min, steel 42CrMo4
Conclusions

- Surface condition have essential influence on Nitriding process successful

- Clean surface does not mean optimal preparation prior Nitriding

- Special care must be focused on machining stages due to Nitriding is last operation to get final product (feedback between designer, tool shop and hardening shop)