Technical Conference: Tube Symposium India 2016

PLASMA ANNEALING OF SMALL DIAMETER TUBES

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Agenda

- Overview of traditional annealing processes for tubes
- Plasma annealing and how it works.
- PlasmaANNEALER and its key components
- Comparing plasma annealing with traditional annealing
- Plasma treatment examples:
  - PlasmaANNEALER for stainless & Ni alloy tubes
  - Plasma surface preparation for coating applications

**SCOPE OF PLASMA APPLICATIONS:**

**Size Ranges:** up to 1 inch OD for continuous process

**Process type:** continuous (OD treatment), batch (OD/ID treatment)

**Materials:** ferrous and non-ferrous
Traditional Annealing Processes for tubes

Strand Annealing Furnace

- Continuous process / low speed / multiline

Induction Annealer

- Continuous process / high speed / single line

Resistive Annealer

- Continuous process / high speed / single line

Batch Annealing Furnace

- Batch process / high output
What is Plasma Treatment?

• **Plasma** = *ionized gas*, contains ions, electrons, radicals

• **Plasma treatment** = *ion bombardment* on material surface
  
  Fire, focused/directed on the material surface

• **Heat treatment**
  
  – annealing
  
  – stress relieving

• **Surface treatment**
  
  – Degreasing
  
  – Surface oxide removal

• **Plasma annealer** =
  
  “High-speed tube/strand annealer”
PlasmaANNEALER Components

- Vacuum System / Gas Supply
- Material Guiding
- Plasma Module: cleaning & heating
- Tempering zone: retains material at temp.
- Cooling System: gas or water or combined

- Cooling System: gas / water
- PLC Controls with HMI
- Plant frame
- Optional: Transport System
- Optional: Payoff and Takeup
# PlasmaANNEALER Quantitative Process Comparison

<table>
<thead>
<tr>
<th>Feature</th>
<th>Strand Furnace</th>
<th>Induction Annealer</th>
<th>Plasma Annealer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Process type</td>
<td>Multi-line / low-speed</td>
<td>Single line / high-speed</td>
<td>Single line / high-speed</td>
</tr>
<tr>
<td>Energy cost</td>
<td>High</td>
<td>Low (steel)</td>
<td>Low</td>
</tr>
<tr>
<td>Purging gas cost</td>
<td>High</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>Labour cost</td>
<td>High</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td>Maintenance cost</td>
<td>High</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td>Production uptime</td>
<td>Low</td>
<td>High</td>
<td>High Immediate start and stop</td>
</tr>
<tr>
<td>Production line footprint</td>
<td>Large</td>
<td>Compact</td>
<td>Compact</td>
</tr>
<tr>
<td>Capex – furnace</td>
<td>Low</td>
<td>Low/high</td>
<td>High</td>
</tr>
<tr>
<td>Capex – payoffs and takeups</td>
<td>High</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td>Working capital locked in material</td>
<td>High</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td>Grain size of finished product</td>
<td>Large</td>
<td>Small</td>
<td>Small</td>
</tr>
<tr>
<td>Annealing power control/temperature control</td>
<td>Limited / Slow</td>
<td>Poor for non-magnetic mat.</td>
<td>Accurate and immediate</td>
</tr>
<tr>
<td>Recrystallization uniformity (stainless)</td>
<td>High</td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>Surface quality</td>
<td>Poor</td>
<td>Subject to setup</td>
<td>High</td>
</tr>
</tbody>
</table>
## Material Samples of Plasma Annealed Tubes

<table>
<thead>
<tr>
<th>Material</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>SUS 304L 8,5mm OD x 0,5mm WT</strong>&lt;br&gt;<em>above:</em> welded tube with oxidation along the weld&lt;br&gt;<em>below:</em> plasma annealed and weld deoxidized</td>
<td></td>
</tr>
<tr>
<td><strong>Ni200 2,5mm OD x 0,2mm WT</strong>&lt;br&gt;<em>above:</em> welded tube, drawn, degreased, surface oxidation&lt;br&gt;<em>below:</em> plasma annealed, deoxidized surface</td>
<td></td>
</tr>
<tr>
<td><strong>NSUS 316L 0,6mm OD x 0,15mm WT</strong>&lt;br&gt;<em>above:</em> drawn welded tube with surface lubricant deposits&lt;br&gt;<em>below:</em> welded tube, plasma annealed for medical applications</td>
<td></td>
</tr>
<tr>
<td><strong>Copper Tube 12mm OD</strong>&lt;br&gt;<em>above:</em> welded tube, surface oxidation, lubricant deposits&lt;br&gt;<em>below:</em> plasma annealed with bright surface finish</td>
<td></td>
</tr>
</tbody>
</table>
PlasmaANNEALER for tubes

For high-speed annealing ferrous and nonferrous tubes

Purging gas options: Hydrogen or Forming gas

Cooling gas / water or combined

Dia. Range up to 20 mm

Output options: various, max 250kg/h for stainless / max 1200 kg/h for copper
PlasmaANNEALER for fine stainless tube

High-speed annealing of stainless steel and medical tubes (speeds up to 10 m/s)

Line configuration options:
- In-line with tube drawing machine
- In-line with rolling mill/ tube welding line
- Off-line as stand-alone annealing line

Hydrogen or combined gas-water cooling

Typical tube size range: OD 0,2 – 3,5 mm
Plasma Annealing Line
for stainless steel tubes dia. 0.5-8.5mm OD
Plasma Surface preparation for coating e.g. tinning

- **Example:** chemical-free surface activation/degreasing for tinning of copper capillary tubes

- Low temperature process, for most application below 150° C

- Simultaneous heat treatment possible

- Various gases can be used to achieve surface activation depending on application/surface condition

- Short compact machine that can operate inline with a coating line

- **Other applications:** plating, painting, spray coating, extrusion coating, taping
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