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AIR WATER INC.

- Profile (As of March 31, 2012) -

Established : September 24, 1929

Head Office : Chuo-ku, Osaka

Number of Employees : 8,062 (Consolidated)

Paid-in Capital : ¥32,263 Million

Net Sales in 2012 : ¥492,680 Million (Consolidated)

Operating Income in 2012 : ¥31,672 Million (Consolidated)
AIR WATER’S BUSINESS FIELDS

- Medical Businesses
- Industrial Businesses
- Energy Businesses
- Other Businesses
- Chemical Businesses
- Logistics Businesses

NV Metal Surface Treatment
NV PROCESS (Contents)

1. NV Nitriding
2. Advantages of NV Nitriding
3. Samples applied NV Nitriding
4. NV Nitriding for Die-casting Dies
5. NV Nitriding for Forging Dies
6. NV Pionite
7. Samples applied NV Pionite
1. NV Nitriding

NV PROCESS
Metal surfaces is covered by Oxide

Oxide is changed to Fluoride

Metal surfaces will be active by the reduction of fluoride.

NV Nitriding is patented technology in major countries.
Temperature and mixture ratio of gases are flexible by Activation Process.
2. Advantages of NV Nitriding
Advantages of NV Nitriding

With the metal surface activation treatment, we have succeeded in greatly advancing the concept of conventional gas nitriding technology.

① The types of metals suitable for nitriding have greatly expanded, from low grade steel to nickel base alloys.

② It is possible to apply stable Nitriding under low temperature. (Nitriding at the temperature of latter of 300°C is available)
   → Minute change in shape and roughness with treatment

③ Nitriding condition is so flexible. Nitriding by low N-potential can be applied easily.
   → The thickness of compound layer or hardness of Nitriding layer is controllable.

④ Nitriding layer can be controlled according to the using condition of the customer.
Accommodation to Nickel base Alloys

- It is possible to apply Nitriding to Nickel base Alloys as a mass production. Wear resistance is improved in high temperature atmosphere without chipping.

(Left : NCF47W, Center : INCONEL718, Right : INCONEL751)
**NV Process**

**Effect of low temperature Nitriding**

- NV Nitriding is possible to realize minute change in shape and roughness.

<table>
<thead>
<tr>
<th>Row material</th>
<th>Roughness</th>
<th>Roundness</th>
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<tr>
<td>SUS316</td>
<td><img src="image1.png" alt="Roughness Image" /></td>
<td><img src="image2.png" alt="Roundness Image" /></td>
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<tr>
<td>NV 380°C</td>
<td><img src="image3.png" alt="Roughness Image" /></td>
<td><img src="image4.png" alt="Roundness Image" /></td>
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<td>(sprayed salt 2400hr)</td>
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<tr>
<td>NV 570°C</td>
<td><img src="image5.png" alt="Roughness Image" /></td>
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<tr>
<td>(sprayed salt 24hr)</td>
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Appearances after salt spray test (SUS316)
Nitriding layer without compound layer which has been difficult by conventional Nitriding methods can be realized by NV Nitriding. NV Nitriding can make harder surface of diffusion layer compared with other Nitriding methods.

Nitriding layer without compound layer is impossible in case of normal condition.

In case that N-potential in Nitriding atmosphere is high (Normal condition)

In case of Nitriding controlled N-potential (No compound layer condition)

NV Nitriding can make both types of Nitriding layer.
Hardness of Nitriding layer is controllable by NV Nitriding, even if it is difficult to control by conventional Nitriding methods.

NV Nitriding can make various types of hardness profiles by Nitriding controlled N-potential, this is realized by activation process.
3. Samples applied NV Nitriding

NV PROCESS
Advantages of NV Nitriding

【Auto motive parts】
① Cost, delivery; Low Nitriding cost and short lead time are realizable by high capacity furnace or on-site system
② Environment; Environmentally friendly technology without cyanide
③ Wear resistance; Stable Nitriding layer on the surface of stainless steels

（Left; SUH11, Right; SUH35）
Advantages of NV Nitriding

【Auto motive parts】
① Prevent welding and scoring；1.5 times in comparison with salt bath Nitriding. 3 times in comparison with raw material.

② Cost, quality；It is possible to make stable layer under setting as a stack.
Advantages of NV Nitriding

【Air conditioner parts】

① Wear resistance; Wear resistance under new refrigerant is available

② Accuracy of dimension; Keeping accuracy of dimension by low temperature Nitriding
Advantages of NV Nitriding

【Air conditioner parts】

① Nitriding for Sintered iron; It is possible to make stable Nitriding layer without influence from sintering additive

② Accuracy of dimension; Low temperature Nitriding is possible by activation

③ Wear resistance; Effect of high-quality Nitriding layer

（Nitriding structure of sintered iron）
Advantages of NV Nitriding

【Auto motive parts】

① Uniformity; Uniform Nitriding layer is realizable even if shape of parts is complex

② Wear resistance; Effect of tough Nitriding layer without porous structure

（Nitriding structure of austenitic stainless steels）
Advantages of NV Nitriding

【 Auto motive parts 】
① No compound layer; No embrittlement problem against thin plate parts
② Uniformity; Uniform Nitriding layer, depth and hardness, is realizable
③ Fatigue strength; Enriched fatigue strength by Nitriding ⇒ 100 times in comparison with raw material

(Nitriding structure of Marageing steels)
Advantages of NV Nitriding (Auto motive parts)

① Fatigue strength; Nitriding layer without compound layer has toughness.

Core hardness can be kept by low temperature Nitriding.

⇒ NV Nitriding can makes 20% higher fatigue strength parts than conventional Nitriding methods
Camshaft

= SCM420

Advantages of NV Nitriding

【Auto motive parts】

① Minute strain; NV Nitriding can make Nitriding layer, which has as high wear resistance as conventional methods, by low temperature Nitriding

② Controlled layer; Optimum depth of Nitriding layer to realize both wear resistance and toughness can be applied by NV Nitriding

( Nitriding structure of SCM420 )
Advantages of NV Nitriding

【Auto motive parts】

① Minute strain; NV Nitriding can make Nitriding layer, which has as high wear resistance as conventional methods, by low temperature Nitriding

② Cost; Low Nitriding cost is realizable by high capacity furnace or customized jigs

（Nitriding structure of alloy steels）
Advantages of NV Nitriding

【Textile machinery parts】
① Wear resistance; Hard and non-porous compound layer made by NV Nitriding can improve wear resistance

② Oxidizing layer; NV Nitriding can make Oxidizing layer on the surface of Nitriding layer. It is more effective for prevention of welding and scoring than conventional Nitriding layer.
Advantages of NV Nitriding

【 Tool, Mold and Die field 】
① Wear resistance ; 1.5 - 2 times in comparison with salt bath Nitriding.
② Chipping resistance ; High toughness layer by controlled hardness profile
③ Cost, delivery ; No transportation cost and short lead time are realizable by on-site system

Aluminum extrusion Dies = Alloy tool steel (SKD61) =
Advantages of NV Nitriding

【 Tool, Mold and Die field 】
① Wear resistance ;  1.5 times in comparison with conventional gas Nitriding.
② Prevent welding and scoring ;  Stable prevention of welding and scoring can be realized by Uniform compound layer
Advantages of NV Nitriding

【Tool, Mold and Die field】
① Uniformity; Uniform Nitriding layer is realizable even if shape of parts is complex or low temperature Nitriding is applied
② Toughness; Nitriding layer without compound layer has high toughness
③ Accuracy of dimension; Keeping accuracy of dimension and core hardness by low temperature Nitriding

（Nitriding structure of SKD11）
4. NV Nitriding for Die-casting Dies

NV PROCESS
Principle of generation of Heat-check

Put aluminum melt $\rightarrow$ Temperature on the surface of die rise

Compressive stress rise on the surface $\rightarrow$ Plastic strain

Spray lubricant $\rightarrow$ Temperature on the surface of die drop suddenly

Tensile stress concentrate on the concave area $\rightarrow$ Heat-check

High temperature

Low temperature
For prevention against Heat-check

- Cause of Heat-check is tensile stress concentration during cooling down

【 Preventive methods 】

① Plastic strain is needed to be decreased during heating up
   ⇒ Strength of dies in high temperature should be kept
   ⇒ Diffusion layer of nitrogen is effective to keep strength during heat cycles.
   (However, excessive hardening worsen, because of embrittlement)

② Compressive stress should be provided against tensile stress
   ⇒ Nitriding which can generate high compressive stress on the surface is effective. (Compound layer worsen, because it may cause crack )

【 Attention points for Nitriding 】

① Thin compound layer is better for crack prevention and welding to modify dies)

② Surface hardness should be optimized in balance between compressive stress and toughness )

③ Diffusion layer should be kept optimum hardness deeply
Hardness control by NV Nitriding

- It’s possible to control hardness of diffusion layer, even if it was difficult by conventional Nitriding methods.
  1. Adjustable ranges of condition are limited in case of conventional Nitriding methods
  2. NV Nitriding can control gases composition flexibly by effect of activation process, therefore hardness of diffusion layer can be easily designed by control of invasion and diffusion of N and C atoms.

Patented technology

Hardness profile for Die-casting dies
- High hardness is only surface area
  ⇒ For wear resistance and prevention against Heat-check
Residual compressive stress

Compressive stress is provided against tensile stress to prevent Heat-crack. Residual compressive stress provided by NV Nitriding for Die-casting dies is 60% higher than the one provided by competitor’s surface treatment for Die-casting dies.
Comparison with normal Nitriding sample

Nominal Nitriding sample

NV for Die-casting dies

Surface hardness HV1000 ~ 1100

Adjustable as same level
**NV Process**

**Result of Heat-Cycle test**

- **Surface after Heat-Cycle test** (\([600°C ⇔\text{Room temp.}] 300 \text{ times}\))

  - **Nomal Nitriding sample**
  - **NV for Die-casting dies**

- **Surface hardness**
  - **Hv1000 \sim 1100**

- **Sample crack deeply. There are rough crack on the surface**
- **Development of crack can be prevented. There are only minute Heat-check.**
Comparison with die applied only quenching and tempering

Point: Level of Heat-check is nearly same even die casted about 30,000 shots more than die of raw material. NV Nitriding is effective for life time of die due to no breakage.
Comparison with competitor’s surface treatment

- Point: These are the surfaces of die after casting 90,000 shots. Surface treatment has been applied 3 times until 90,000 shots. Level of Heat-check is better than competitor’s surface treatment.
Point: NV Nitriding can realize improvement of 30% of life time.

Comparison with competitor’s surface treatment

After casting 90,000 shots

After casting 120,000 shots
5. NV Nitriding for Forging Dies

NV PROCESS
**Feature of NV Nitriding for forging dies**

1. **Uniform Nitriding layer**
   - Uniform Nitriding layer is realizable by NV Nitriding even if shapes of dies are complex.

2. **Prevention of welding and scoring**
   - Improvement of sliding frictional behavior of welding and scoring can be realized by uniform compound layer and oxide layer on the surface.

3. **Shock resistance and crack resistance**
   - Improvement of shock resistance can be realized by hardness control of Nitriding layer. (It is also possible to avoid softening core hardness by low temp. Nitriding)

4. **Modification (re-sink)**
   - Modification (re-sink) of dies is available by NV Nitriding or control of Nitriding layer.
Uniformity of NV Nitriding (SKD61 equivalent)

Surfaces of die

Micro structure (×600)

Uniform compound layer (ε-layer)

Diffusion layer (CrN precipitate)

Slight Nitriding layer

In case of complex shape, Nitriding layer is unstable
Sliding frictional behavior and prevention of welding and scoring can be improved by existence of uniform compound layer and Fe₃O₄ on the surface which is made by NV Nitriding for forging dies.

- Fe₃O₄
  - Effective for bedding-in pattern, prevention of welding and scoring, retention of release agent (Improvement sliding frictional behavior)

- Uniform ε-layer (Fe₃N)
  - Effective for wear resistance, prevention of welding and scoring

- Fe (Solute N) + Fe₄N
  - Effective for toughness of surface area
Shock resistance

Improvement of die life or continuous forging without maintenance is possible

NV Nitriding

Salt Nitrosulphurizing

Die life is above, but shear-dropped is occurred after following shots.

Dies applied NV: 8,500 shots
Salt Nitrosulphurizing: 3,000 shots
Crack resistance

- Toughness of hardened layer can be improved

**NV Nitriding**

Toughness evaluation by Rockwell (C-scale)

**Ion Nitriding**

Many cracks

Fatigue strength is so improved by relieving embrittlement ⇒ Crack resistance is improved under loading repeated stress

Rotary bending fatigue testing

Stress (MPa)

NV

Ion

Raw material

Cycle