PTA Hardfacing Technology and Application Introduction
Shanghai Domu Industrial Co., Ltd. is a high-tech company specialized in the automatic welding machine of research, development and sales. Now we get a leader in the market through experience for ten years in the industry. At present, we have set up the base of industry research by cooperating with Ji Lin University and so on. Meanwhile, we own the senior manufacturing engineer and designers with the initiative spirit to device development. A super team devoted to provide the professional solution and service. So far, the authorized patent we applied for is up to more than ten items. Our core technology of welding make up for the gap domestic and overseas that bring out the benefit of social and economy.
• PTA Hardfacing Brief Introduction;
• PTA Equipment Brief Introduction;
• PTA Powder Application and Selection
• Comparing with conventional arc surfacing technologies
• PTA Industrial Application
1. PTA Hardsurfacing Brief Introduction

1.1 Mechanism
As an advanced surface modification technique, Plasma Transferred Arc (PTA) hardsurfacing is increasingly widely applied for protection or/and refurbishment of metallic wear, such as adhesion, abrasion, corrosion, erosion, fatigue, cavitation, etc. By using argon as plasma generating gas, a pilot gas (non-transferred arc) was easily ignited at the beginning. Plasma arc as the heat resource, alloy powder were feeding into the arc then melting as metallurgical bond layer finally.
1.3 PTA Characteristics

- 1. Cladding layer is connected with work piece by a high strength bonding as metallurgical bond form.
- 2. Low and controllable dilution which can be under 5%, less heat input, means less deformation.
- 3. High density and good welded appearance, less machining job if any machining require.
- 4. Powder can be mixed and selected in accordance with specific wear resistance require.
- 5. Easy to integrate and combine with automatic hard and soft ware, increase efficiency and products quality.

Dilution

- According to welding metallurgy, while welding some of parent material elements, it will be dissolved into the welding pool and diluting its composition.

\[ \text{% dilution} = \frac{B}{A+B} \times 100 \]
1.2 Forming mechanism of plasma arc

Plasma arc is a kind of high energy, density and temperature ion arc, which is compressed by a free arc. There are 3 major compression methods:

1. **Mechanical compression**
   To use the orifice diameter of the nozzle to restrain the plasma arc makes the energy density and temperature of the arc column increased -- mechanical compression effect.

2. **Thermo compression**
   The nozzle is with a certain flow of cooling water to reduce the temperature of the nozzle. When the arc column passes through the nozzle orifice, a layer of cold air film is formed on the inner wall of the nozzle due to the lower temperature, of which the conductive section decreases. And the current density and temperature to further increase -- hot compression effect.

3. **Magnetic shrinkage**
   Magnetic shrinkage The magnetic field generated by the arc current makes the arc column to contract centripetal to reducing its section. The higher the current density, the stronger the shrinkage effect -- magnetic shrinkage effect.
Plasma cladding equipment structure

- Plasma generator
- Feeding system
- Torch

Structure drawing
2.2 Plasma cladding power supply introduction

Plasma power mainly composed of transfer arc and non-transfer arc. It is to draw the transfer arc (main arc) through the non-transfer arc (dimensional arc)

- Typical PTA operations begin with the striking of the pilot arc, followed by the initiation of the transfer arc,
- The pilot arc is struck between the constrictor nozzle and the tungsten electrode, using a high-frequency generator, and creates a low-resistance “pathway” from the electrode tip to the workpiece.
- The transfer (plasma) arc, when ignited, follows this low-resistance pathway to the workpiece, creating a weld pool at the substrate. Deposition occurs when the metallic powder is carried through the plasma arc, where it is melted and deposited into the weld pool.
- Kennametal
2.2 Photography
Precise inspection to torch

infrared imaging

vancurm gas flow
2.3 Powder feeder

**operating principle**

The working principle of the powder feeder is to drive the powder wheel to rotate through the transmission motor and to send the alloy powder to the torch by the gas. Adjusting the speed of the motor can be changed the volume of feed powder.

**The name of the parts**

1. Inlet
2. Outlet
3. Additing
4. Reservoir
5. Body
6. Window
7. Release valve
2.4 Torch

The torch is the core unit. It is composed of the system of recycled water, circuit, gas circuit, and powder pipe. It measures the service life of torch relevant to high temperature resistance, gas tightness, and insulativity.

The torch with casting is well received by the market.

The parts:
1. Shielding nozzle
2. Copper locking ring
3. Copper nozzle
4. Focus ring
5. Torch body
6. Electrode
7. Clamper
8. Cap
9. Handle
2.4 Cooling System

• Normally there are two kinds of chiller, air cooling and liquid cooling, liquid cooling is widely applied in PTA. It has a good performance to torch.

• Pour proper water into tank, the water is cooling via the refrigerator, then it has been sent to target device by pump. After that, the temperature of the cooling water rise after the heat is taken away. Last, it goes back to tank to get to the cooling. The temperature is between 9-15.
2.4 Features of process
### 2.4 Differences of PTA and Laser

<table>
<thead>
<tr>
<th>PTA</th>
<th>Laser</th>
</tr>
</thead>
<tbody>
<tr>
<td>NI+35Wc</td>
<td>NI60</td>
</tr>
<tr>
<td>HRC62</td>
<td>HRC60</td>
</tr>
</tbody>
</table>

![PTA Image](image1)

![Laser Image](image2)
2.4 PTA Automatic Equipment
2.4 Comparison of PTA and SAW
3. PTA Powder Application and Selection

Normally it is according to the working environment and needs to select the powder. There are four types of the powder.

- Fe (Iron-base)
- Ni (Nickel base)
- Co (Cobalt base)
- Cu (Copper base)
3.1 Iron Base Powder

Fe-base powder is come from Fe-C alloy with addition appropriate amount of Boron, Silicon, normally apply for under 500 degree temperature and gentle acid or alkaline corrosion application, nevertheless its comprehensive property is not as well as Ni and Co base powder, its raw material are widely provided and manufacturing cost is lower.

**Fe-base powder can be divide into 2 groups as: stainless steel and high carbon high chromium**

The cold layer of austenitic stainless steel self fluxing alloyed powder is structure from austenite and variant carbide, with moderate wear resistant and erosion resistant ability, better than normal austenite SS such as 1Cr18Ni9Ti, 2Cr13.

High carbon and high chromium alloyed powder consist of high percentage of carbon and chromium, and some carbide, boron compounds, with a good hardness and wear resistant, but not so excellent machining ability.
## 3.1 Iron Base Powder

<table>
<thead>
<tr>
<th>Powder</th>
<th>Hardness</th>
<th>Component</th>
<th>Technology</th>
<th>Fineness</th>
<th>Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fe1</td>
<td>35-400.15</td>
<td>Cr  22 Si 4.5 Fe 2 Mo 13 Ni 1.6 Remain B 1.6</td>
<td>PTA / Laser</td>
<td>100/270</td>
<td>Valve</td>
</tr>
<tr>
<td>Fe2</td>
<td>38-440.15</td>
<td>Cr  22 Si 4.5 Fe 2 Mo 10 Ni 1.8 Remain B 1.8</td>
<td>PTA / Laser</td>
<td>100/270</td>
<td>Valve seat</td>
</tr>
<tr>
<td>Fe5</td>
<td>62-674.5</td>
<td>Cr 40 Si 1.0 Fe 0.971.8 Remain B 1.8</td>
<td>PTA / Laser</td>
<td>100/270</td>
<td>Drill joint</td>
</tr>
<tr>
<td>Fe90</td>
<td>50-550</td>
<td>Cr 0.15 Si 13.5 Fe 1.6 Remain B 1.6</td>
<td>PTA / Laser</td>
<td>100/270</td>
<td>Drill joint</td>
</tr>
<tr>
<td>Fe6</td>
<td>58-60</td>
<td>Cr 0.8 Si 7.5 Fe 32 Remain B 4</td>
<td>OXY spray / PTA</td>
<td>100/270</td>
<td>Ventilator blade</td>
</tr>
<tr>
<td>Fe45</td>
<td>40-46</td>
<td>Cr 0.6 Si 7.5 Fe 22 Remain B 3</td>
<td>OXY spray / PTA</td>
<td>100/270</td>
<td>Paper mill</td>
</tr>
<tr>
<td>Fe304</td>
<td>HB190</td>
<td>Cr 0.03 Si 18 Fe 10 Remain B 0.3</td>
<td>PTA / Laser / Ultrasonic spray</td>
<td>100/270.300/500</td>
<td>Paper mill</td>
</tr>
<tr>
<td>Fe316L</td>
<td>HB190</td>
<td>Cr 0.03 Si 17 Fe 2.5 Remain B 12</td>
<td>PTA / Laser / Ultrasonic spray</td>
<td>100/270.300/500</td>
<td>Paper mill</td>
</tr>
</tbody>
</table>
### 3.2 Nickel Base Powder

The powder can be divided into 2 groups that they are Ni-B-Si and Ni-Cr-B-Si

The microstructure of cladding layer of Ni-B-Si alloy is composed of Ni-Si solid solution (Y phase), various borides (Y ‘phase) and Y - Ya’ eutectic phase. The alloy has low hardness, good toughness, high temperature resistance, wear resistance, corrosion resistance and easy machining. diffuse distribution

The microstructure of cladding layer of Ni-Cr-B-Si self-melting alloy is complex. It is composed of nickel-chromium solid solution, nickel boride, chromium boride and other phases, and carbide of chromium, carbide of boron, carbide of tungsten and other hard phases. This kind of alloy still has high hardness, wear resistance and corrosion resistance at 500°C.
3.2 Ni Base Powder

Image 5  Ni60,12496 heatt hardness of alloy
1. Ni 60 Cap component
2. 12496 (Switzerland)
3. Ni 60 limit component
4. Ni 60 Minimum component

Corrosion rate of nickel base alloys with different iron contents in solution at room temperature
3.2 Nickel Base Alloy Powder

Test result:
The locations of hardness test points are shown in Figure 3.
Hardness values are listed in Table 2.
Approx.
0.040 in (1mm)

![Figure 3 Indentation position](image)

![Figure 4 Microstructure of sample weld](image)

<table>
<thead>
<tr>
<th>Area</th>
<th>HV10</th>
<th>Area</th>
<th>HV10</th>
<th>Area</th>
<th>HV10</th>
<th>Area</th>
<th>HV10</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>756</td>
<td>6</td>
<td>834</td>
<td>11</td>
<td>620</td>
<td>16</td>
<td>367</td>
</tr>
<tr>
<td>2</td>
<td>883</td>
<td>7</td>
<td>740</td>
<td>12</td>
<td>501</td>
<td>17</td>
<td>368</td>
</tr>
<tr>
<td>Close to surface</td>
<td>906</td>
<td>8</td>
<td>923</td>
<td>13</td>
<td>518</td>
<td>18 Base</td>
<td>377</td>
</tr>
<tr>
<td>4</td>
<td>912</td>
<td>9</td>
<td>807</td>
<td>14</td>
<td>533</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>5</td>
<td>871</td>
<td>10</td>
<td>818</td>
<td>15</td>
<td>605</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Table 2 Sample hardness results
3.2 堆焊粉末的设计

常用的喷/堆焊混粉多是通过向自熔合金粉末中添加其他强化合
合粉末（如硬质合金）得到。

自熔合金
本身具有良好脱氧、除渣、
和良好浸润性能

硬质合金
硬度高、耐磨性好

铸造碳化钨
单晶碳化钨
球形铸造碳化钨

其他强化元素Mn、Cr等

Ni基自熔合金粉
Co基自熔合金粉
Fe基自熔合金粉

焊层硬度高、耐磨性好、
和孔隙少
# 3.2 Nickel Base Powder

<table>
<thead>
<tr>
<th>Powder</th>
<th>Hardness</th>
<th>Component</th>
<th>Others</th>
<th>Granularity</th>
<th>Application</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>C   Cr</td>
<td>Si</td>
<td>W</td>
<td>Fe</td>
</tr>
<tr>
<td>Ni5AA</td>
<td>15</td>
<td>0.63</td>
<td>0.46</td>
<td>2.3</td>
<td>0.46</td>
</tr>
<tr>
<td>NI20M</td>
<td>20</td>
<td>0.03</td>
<td>4.5</td>
<td>2</td>
<td>Remainder</td>
</tr>
<tr>
<td>NI22AA</td>
<td>22</td>
<td>0.2</td>
<td>0.1</td>
<td>2.85</td>
<td>0.5</td>
</tr>
<tr>
<td>NI22M1</td>
<td>26</td>
<td>0.03</td>
<td>0.5</td>
<td>3</td>
<td>0.5</td>
</tr>
<tr>
<td>Ni25</td>
<td>25</td>
<td>0.2</td>
<td>3.5</td>
<td>8</td>
<td>Remainder</td>
</tr>
<tr>
<td>Ni50AA</td>
<td>50</td>
<td>0.45</td>
<td>11</td>
<td>4</td>
<td>2.7</td>
</tr>
<tr>
<td>Ni55</td>
<td>53</td>
<td>0.4</td>
<td>15</td>
<td>4.3</td>
<td>5.0Max</td>
</tr>
<tr>
<td>Ni65AA</td>
<td>56</td>
<td>1.0</td>
<td>10</td>
<td>5.3</td>
<td>5.0Max</td>
</tr>
<tr>
<td>Ni60AA</td>
<td>60</td>
<td>0.78</td>
<td>15.8</td>
<td>4.55</td>
<td>5.0Max</td>
</tr>
<tr>
<td>NI60A</td>
<td>60</td>
<td>0.7</td>
<td>15</td>
<td>4.0</td>
<td>8.0Max</td>
</tr>
</tbody>
</table>
3.2 Nickel Base Powder/Blending Cemented Carbide

Although nickel powder has a comprehensive property, but in some tough working environment, using life is not as good as expected. To harden its wear resistant, add some percentage of hard particle.
3.4 Cobalt Base Powder

Co-base self fusion powder is developed from stellite alloy. It is a known fact that stellite is a kind of excellent high temperature alloy, has good heat resistance, hot corrosion, toughness, cold or hot fatigue performance. It is majorly consist of Co, Cr, W, so called Co-Cr-W alloy meanwhile. And add some B Si then can form Co-base self fusion powder. It is normally can working in above 600 degree with excellent heat resistance ability.

Co-base self fusion powder can apply in precious product as high temperature corrosion for instance high temperature and high pressure valve, sealing plate of exhausting valve in motor, and engine components of aircraft cause from hot corrosion.
# 3.4 Co Base Powder

<table>
<thead>
<tr>
<th>Powder</th>
<th>Hardness</th>
<th>Component</th>
<th>Granularity</th>
<th>Application</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>C  Cr  Si W  Fe  Mo  Ni  Co  Mn  P</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CoOl</td>
<td>48-54</td>
<td>2.4  30  1  12  *0.0  ± 1.00  *0.0  Remainder  W1.00</td>
<td>100/270</td>
<td>Seat, bearing, knife or rotary seal ring, etc.</td>
</tr>
<tr>
<td>Co03</td>
<td>48-54</td>
<td>23   30  1  12  *0.0  /  *3.00  Remainder  /</td>
<td>100/270</td>
<td>Needle seat, guide roll, valve seat.</td>
</tr>
<tr>
<td>C006</td>
<td>38-44</td>
<td>1.2  30  1  4.5  W3.00  moo  Remainder  1.00</td>
<td>100/270,300/500</td>
<td>Turbine blade.</td>
</tr>
<tr>
<td>Co56</td>
<td>40-45</td>
<td>1.6  28  1.1  4.0</td>
<td>Remainder</td>
<td>100/270</td>
</tr>
<tr>
<td>C006H</td>
<td>43-48</td>
<td>1.3  30  1.5  5.5  3.00Max  0.8  3.00Max  Remainder  1.0Max</td>
<td>100/270</td>
<td>Engine valve, High pressure valve, vortex Turbine blade, etc.</td>
</tr>
<tr>
<td>Co2</td>
<td>42-48</td>
<td>1.4  29  1.4  8.5  *0.0  ± 1.00  *3.00  Remainder  W1.00</td>
<td>100/270</td>
<td>High temperature and high pressure valves, serrated</td>
</tr>
</tbody>
</table>
3.5 Cu Base Powder

Copper powder, consisted of alloy of Sn, Ma that is with B and Si, is less application than the one of nickel, cobalt and iron. In addition to this, the advantage of Phossy of reducing the melting point and wetting the base easily that the copper contained a certain amount of would be self-fluxing well.

The surfacing layer with copper has the excellent properties of toughness, electrical and thermal conductivity.

The Copper powder was adopt in the technology of plasma cladding that greatly saves the manufacturing cost and has a extensive use, especially in valve industry.

<table>
<thead>
<tr>
<th>Powder</th>
<th>Component (Weight %)</th>
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<tbody>
<tr>
<td></td>
<td>C</td>
</tr>
<tr>
<td>TCu1</td>
<td>2</td>
</tr>
<tr>
<td>TCu2</td>
<td>2</td>
</tr>
<tr>
<td>TCu3</td>
<td>1</td>
</tr>
<tr>
<td>TCu4</td>
<td>AL10</td>
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</table>
### 4.1 Comparing PTA with conventional hardfacing

<table>
<thead>
<tr>
<th>Welding</th>
<th>Dilution (%)</th>
<th>Powder feeding (Kg/h)</th>
<th>Claded thickness one layer (mm)</th>
<th>Consumables</th>
</tr>
</thead>
<tbody>
<tr>
<td>PTA</td>
<td>5</td>
<td>12</td>
<td>0.25</td>
<td>Powder</td>
</tr>
<tr>
<td>TIG</td>
<td>15</td>
<td>2.5</td>
<td>2.5</td>
<td>rod</td>
</tr>
<tr>
<td>FSW</td>
<td>1</td>
<td>1.8</td>
<td>1.2</td>
<td>Powder rod</td>
</tr>
<tr>
<td>SAW</td>
<td>20</td>
<td>10-20</td>
<td>4.0</td>
<td>wire</td>
</tr>
<tr>
<td>GTAW</td>
<td>20-30</td>
<td>6-10</td>
<td>3-4</td>
<td>wire</td>
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</tbody>
</table>
4.2 Comparing PTA with conventional welding

<table>
<thead>
<tr>
<th>Unmber</th>
<th>1#</th>
<th>2#</th>
<th>3#</th>
</tr>
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<tbody>
<tr>
<td>Powder</td>
<td>YZ+Ni50</td>
<td>YJ+Ni60</td>
<td>YZD+Ni50</td>
</tr>
<tr>
<td>Parent Material</td>
<td>45#</td>
<td>45#</td>
<td>45#</td>
</tr>
<tr>
<td>Current</td>
<td>140A</td>
<td>140A</td>
<td>140A</td>
</tr>
<tr>
<td>Feeding speed</td>
<td>65g/min</td>
<td>65g/min</td>
<td>65g/min</td>
</tr>
<tr>
<td>Welded sample thickness</td>
<td>3.5mm</td>
<td>3.5mm</td>
<td>3.6mm</td>
</tr>
<tr>
<td>Hardness</td>
<td>55.6HRC</td>
<td>62.3HRC</td>
<td>60.8HRC</td>
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<tr>
<td>Volume loss</td>
<td>17.32mm³</td>
<td>23.95mm³</td>
<td>14.54mm³</td>
</tr>
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</table>
## 4.3 PTA /FS/HVOF

<table>
<thead>
<tr>
<th>process</th>
<th>PTA</th>
<th>FS</th>
<th>HVOF</th>
</tr>
</thead>
<tbody>
<tr>
<td>粉末</td>
<td>自熔合金 (或为基体)</td>
<td>自熔合金 (或为基体)</td>
<td>不受限制</td>
</tr>
<tr>
<td>前处理</td>
<td>除油、除锈</td>
<td>除油、除锈</td>
<td>除油、除锈喷砂</td>
</tr>
<tr>
<td>预热</td>
<td>不需要</td>
<td>需要</td>
<td>不需要</td>
</tr>
<tr>
<td>重熔</td>
<td>不需要</td>
<td>需要</td>
<td>不需要</td>
</tr>
<tr>
<td>工件形状</td>
<td>规则</td>
<td>无限制</td>
<td>规则</td>
</tr>
<tr>
<td>自动化程度</td>
<td>手动或自动</td>
<td>手动或自动</td>
<td>自动</td>
</tr>
<tr>
<td>焊层孔隙率</td>
<td>&lt; 1%</td>
<td>&lt; 10%</td>
<td>&lt; 0.5%</td>
</tr>
<tr>
<td>结合强度</td>
<td>&gt; 350MPa</td>
<td>100-350MPa</td>
<td>≤80MPa</td>
</tr>
<tr>
<td>最大沉积率</td>
<td>95%</td>
<td>70%</td>
<td>55%</td>
</tr>
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</table>
4.4 Powder preheating procedure
4.4 Powder preheating
PTA设备选型
The difference between wire and powder

**Powder**
- All made of alloy powder
- The deposition rate and bonding strength are good
- No splash during surfacing
- The heat affected area is small
- The microstructure of the alloy is evenly distributed

**Welding stick**
- It's made of powder and iron
- Large proportion of Fe in surfacing layer
- Poor appearance uniformity
- Suitable for thick workpiece surfacing
4.1 PTA粉末选型建议 Powder selection

- 根据表面硬度确定界面材料
  - consider surface hardness
- 根据母材成份选定合适的增材粉末
- 结合后期加工选择合适的工艺及材料
- 根据修复位置及处理面积选定合适工艺
4.2 PTA粉末选型建议

- 因为各种材料的使用温度不同，所以需要根据使用温度进行选型。
  - different material has its own property in different temperature working environment

- 根据介质不同，判断耐磨、耐腐蚀、耐冲击工况。
  - different wear medium determine different wear corrosion precussion etc

- 根据工作方式（滑动摩擦、滚动摩擦、冲击磨损等）
  - different friction type such as slide or rolling or mixture

- 根据客户对堆焊层使用寿命的预期，进行材料选型。
  - depending on customer’s expectation of life cycle

- 根据后期加工方式不同选择不同的材料。
  - depending on subsequent producing method and its requirement
4.3PTA粉末选型建议

硬度 (hardness)
耐磨性能 (wear)
耐腐蚀性能 (corrosion)
表面裂纹 (crack)
抗冲击性能 (impact/precision)
抗拉强度 (tensile strength)
实际工况测试 (trial)

评估标准是什么呢？
what indeed the selecting criteria？
## PTA堆焊常见问题/frequent imperfections

<table>
<thead>
<tr>
<th>缺陷类型</th>
<th>形状</th>
<th>产生位置</th>
</tr>
</thead>
<tbody>
<tr>
<td>气孔 pore</td>
<td>单个或多个圆形孔洞</td>
<td>※起弧处焊层底部，数量较少。 ※不规则分别在焊道上，数量较多</td>
</tr>
<tr>
<td>裂纹 cracks</td>
<td>※单道裂纹，垂直于焊道方向，长度和焊道宽度相当，深度和焊道厚度相当 ※产生于焊道中心，和焊道方向一致的中心裂纹。</td>
<td>※起弧收弧处附近。 ※随机分布</td>
</tr>
<tr>
<td>未熔合 Non fusion</td>
<td>※焊层和母材没有完全熔合，从母材结合面处脱落。</td>
<td>※可发生于焊道任何位置</td>
</tr>
<tr>
<td>疏松</td>
<td>※堆焊层内部存在的细小孔洞，渗透探伤时可见细微斑点状、团状或线状缺陷显影。</td>
<td>※一般发生在收弧处</td>
</tr>
<tr>
<td>缩孔 shrinkge</td>
<td>※形状、大小不规则的孔洞或塌陷</td>
<td>※可发生于焊道任何位置</td>
</tr>
<tr>
<td>层间脱落</td>
<td>※焊层与焊层为熔合脱落</td>
<td>※多层堆焊时可发生于焊层任何位置</td>
</tr>
</tbody>
</table>
5. PTA Industry Application

**Oil & Chemistry Industry**
- Oil & Gas Drilling: PDC Driller, Screw Screw, Plunger, Steering Tool, TC Bearing
- Oil Refining: Valve, Plunger

**Mining Tools Industry**
- Mining Drilling: Mining Teeth, Rotary Teeth, Trenching Teeth, Geological Driller

**General Machinery Industry**
- Plastic Machinery: Screw, Plunger
- Glass Molds
- Cutting Tools: Cutter, Blade
PDC钻头
应用部位：保径部位
应用材料：Ni+WC
效果：自动化程度大幅提高，耐磨性能优异。

螺杆钻具
应用部位：扶正器 弯壳体
应用材料：Ni+WC
效果：在保证耐磨的情况下兼顾耐冲击性能。

TC轴承
应用部位：TC块与本体的间隙
应用材料：Ni+WC
效果：
五、PTA行业应用
五、现场
五、现场
企业资质
合作伙伴

服务企业超过1000家