ABSTRACT

Cold Gas Spraying is a newer coating technology related to the field of Thermal Spraying. Compared with other thermal spray techniques, the particles are not melted prior to impact and thermal stressed. The physical and chemical properties of the mainly metallic coatings are close to the source material. The CGT modular systems enable a broad range of metals and alloys, e.g. Aluminium, Copper, Titanium, Inconel or Ti6Al4V, to be used to produce mainly high quality coatings. Cold gas is very well suited for production of thick parts and structures, as it is required e.g. in rapid prototyping or for free-standing parts. The potential of cold spray for producing complex parts is evaluated.

1. INTRODUCTION

Cold spraying has established itself on the market as an innovative method for coating, repairing and manufacturing finished components. Compared to conventional thermal spraying, cold spraying is relatively simple to implement: A highly pressurized gas, typically nitrogen, is preheated and then expanded in a converging/diverging De Laval type nozzle (Fig.1). Through a separate gas line, a fluidized powder feedstock is fed into the smallest diameter of the nozzle or further upstream. The powder is accelerated by the gas stream and impacts the substrate with velocities between 200 and 1200 m/s, depending on particle sizes and material. Contrary to thermal spraying the substrate and sprayed material is not melted but only barely heated. The comparatively low process temperatures, the very short time scales and the use of more or less inert process gases make the cold spray process suitable for applications where it is vital to avoid oxidation and to retain properties of the powder feedstock in the sprayed coatings. First industrial applications include, for instance, deposition of oxygen free copper coatings where high electrical and thermal conductivity are critical required.

Approximately half of the systems delivered by CGT are destined for the production industry where there are more than 30 larger series applications for cold spraying. The mostly used Kinetiks®4000 series operates at pressures of 20 to 40 bar. These modular systems designed for different heat outputs enable a broad range of materials to be used to produce high-quality coatings. To open up new areas of application two further products were developed, namely Kinetiks®2000 and Kinetiks®8000 which extend the output range of the Kinetiks®4000 series even more. All CGT systems are high pressure cold spray systems. The powder is injected into the gas jet before the narrowest cross-sectional area of the nozzle. This feature distinguishes them from the low-pressure systems where the powder injection takes place behind the narrowest cross-sectional of the nozzle and particle velocities which can be reached are thus generally lower.

2. SYSTEM OVERVIEW

2.1 Kinetiks®2000

The Kinetiks®2000 is a portable system with a light-weight spray gun which can be operated by hand. In contrast to the other CGT systems, the gas pressure is limited to 20 bar and the gas temperature to 400°C. The system is primarily intended for the use in maintenance and repair operations, e.g. for corrosion protection. The range of sprayable materials includes
those metals which are important for corrosion protection, e.g. aluminium, zinc and tin.

2.2 Kinetiks®4000

The modular system Kinetiks®4000 is designed for a maximum pressure of 40 bar and different heat outputs ranging from 17 to 47 kW. All versions have a filament heater with an output of 17kW integrated in the gun. With an additional 17 kW or 30 kW heater the spray process can be conducted at gas temperatures of up to 800°C with nitrogen or helium. When using nitrogen the maximum gas consumption is 80 to 90 Nm³/h. Typically 5 Kg with the use of copper can be sprayed per hour with a deposition efficiency of nearly 100%.

2.3. Kinetiks®8000

The Kinetiks®8000 was developed to render the spray process more efficient for applications in which the spraying times, in particular, need to be kept as short as possible. The gun is equipped with filament heater with an output of 25kW. In combination with two gas heaters the maximum heat output is boosted to 85 kW. The gas consumption is up to 160m³/h. This enables more than 10kg/h of deposition with the use of copper.

3. SUITABILITY OF THE KINETIKS® SERIES FOR A VARIETY OF MATERIALS

Powders which are suitable for cold spraying generally demonstrate a high plastic deformability (ductility) under extremely high strain. These include pure metals as well as alloys. Material mixtures are suitable for coating formation if these are embedded in a ductile metal matrix. In order to form a coating, the powder particles must reach a minimum velocity, the so-called critical velocity, when impacting on the substrate. If material abrasion is higher than deposition on the other hand, erosion velocity is reached. The range for optimum deposition and coating formation is referred to as the window of deposition and is limited by both variables. This velocity is dependent on the material used. Deposition saturation is a prerequisite for optimum coating formation.

Materials which are sprayable include:

Metals: e.g. Cu, Al, Ni, Ti, Ta, Nb
Alloys: e.g. Inconel, MCrAlY’s, Ti6Al4V
Mixed Materials: e.g. ductile metal matrix with hard materials like ceramics.

4. APPLICATIONS

Cold spray has established itself on the market as an innovative method for coating, repairing and manufacturing finished components. The CGT modular systems enable a broad range of metals and alloys, e.g. Aluminium, Copper, Titanium, Inconel or Ti6Al4V, to be used to produce mainly high quality coatings. Cold gas is very well suited for production of thick parts and structures, as it is required e.g. in rapid prototyping or for freestanding parts. This is especially interesting for materials with high strength or high melting points, for which forming is difficult and requires high temperatures. The potential of cold spray for producing complex parts e.g. in the aircraft industry is evaluated.

With our new Kinetiks®8000-HP system, running with nitrogen as the process gas, high deposition efficiencies of more than 95% can be obtained with the use of pure titanium or Ti6Al4V. The coatings show porosities below 1% and high tensile strength of 450 MPa. Cold spraying is as well suited for manufacturing of metastable phases due to the low process temperatures. Using conventional thermal spray technologies the photocatalytic metastable Anatase-TiO₂ turns into non-active Rutile-TiO₂ due to the high process temperature. In cold gas sprayed coatings no phase transition can be observed: The coatings have nearly the same photocatalytic activity than the reference powder. Cold gas spraying provides distinct advantages to conventional
coating technologies and could help to foster the rise of TiO$_2$-based applications in environmental technologies.
COLD GAS Spraying

Cold Spray Systems And Components From CGT GmbH
For The Production Of High End Metal Coatings

E. Bähr, Titanium 2010,
Orlando/Florida
What is Cold Spray?

- newer thermal spray technology

- compared with other thermal spray techniques: particles are not melted prior to impact

- physical and chemical properties of mainly metallic coatings close to source material
The Principle of Cold Spray

- Inside a hot gas jet, powder particles are accelerated to supersonic velocities and impact in solid state onto a substrate.
- Particles are injected into the gas jet so that they are barely heated.
- Because of high kinetic energy, particles are heavily deformed and bonded on a substrate – dense and good adhering coatings are formed.
Coatings

Properties of Cold Spray Coatings

- low porosity
- low oxygen content
- low thermal load of coating materials

- electrical and thermal conductivity reach more than 90% of bulk material
- physical and chemical properties of bulk material
- coatings of excellent quality concerning bonding and mechanical properties are produced
Applications

Coating

Repairing

Spray Forming
Coating materials

- **metals**: Al, Ti, Ni, Cu, Ta, Nb, Ag, Au…..
- **alloys**: Ti, Nickel-Chromium, Brass, Bronze, MCrAlY’s…..
- **mixed materials**: metal matrix wear resistant materials. e.g. metal and ceramics

Base materials

- metal engineered parts, plastics as well as glass and ceramics
# Applications

<table>
<thead>
<tr>
<th>Application</th>
<th>Material/Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sputter targets</td>
<td>Ta – Nb – Ti … (pure without oxyde)</td>
</tr>
<tr>
<td>Propeller blades</td>
<td>Al 6061 (shape repair)</td>
</tr>
<tr>
<td>Nuclear industry</td>
<td>Ta – Zr – Ti (corrosion resistance)</td>
</tr>
<tr>
<td>Car manufacturing</td>
<td>Cu (electrical contacts in spot welding)</td>
</tr>
<tr>
<td>Aircraft industry</td>
<td>Ni-based (structural repair)</td>
</tr>
<tr>
<td>Aircraft gearboxes</td>
<td>Al (corrosion repair)</td>
</tr>
<tr>
<td>Printing industry</td>
<td>Braze – Zn (engraving surface)</td>
</tr>
<tr>
<td>E-Motors</td>
<td>Cu (high performance syncron engines)</td>
</tr>
<tr>
<td>...</td>
<td></td>
</tr>
</tbody>
</table>
Coating
Coatings

- Ti6Al4V: TCT-test: 450 MPa
- Nickel: TCT-test: 300 MPa
- Ta Coating (N2): TCT-test: 290 MPa
- MCrAlY: TCT-test: 450 MPa
tantalum for chemical industry and medicine

Tantal-Valves for the mining industry –
price per unit  50.000.- up to 1,3 Mio€
Repairing
C-160 Propeller Blade Repair

extensively worn blade

pre-ground

coating process

shape-ground

polished/anodized

www.praxair-gmbh.de

www.praxair.com
Spray Forming
The future. Spray Forming.

Spraying of Thick Coatings
repair applications, spray forming, rapid prototyping

sprayed steel ring
coating thickness: 10 mm
spraying time: 5 min
on Cu-tube 42 mm

machinable Ti coating
on Al tube
The future. Spray Forming.

Production of titanium/alloy tubes and nearly ned shaped parts for the aircraft industry.
The CGT Systems

high pressure.....high quality
Principle of CGT Cold Spray System
<table>
<thead>
<tr>
<th>System</th>
<th>Nitrogen</th>
<th>Helium</th>
<th>max. pressure</th>
<th>Materials</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kinetiks®4000/17-S</td>
<td>550°C</td>
<td>-</td>
<td>40 bar</td>
<td>e.g. Zinc, Aluminium, Tin</td>
</tr>
<tr>
<td>Kinetiks®4000/34-X</td>
<td>800°C</td>
<td>600°C</td>
<td>40 bar</td>
<td>e.g. Nickel, Copper</td>
</tr>
<tr>
<td>Kinetiks®4000/47-M</td>
<td>800°C</td>
<td>800°C</td>
<td>40 bar</td>
<td>high end materials like Niobium or Tantalum</td>
</tr>
</tbody>
</table>

1 optional; 2 obligatory
Kinetiks 8000

85 KW
Up to 40 bar
up to 160 m$^3$/h gas flow
Up to 1000°C (Nitrogen)
material amount/h: 16-18kg*

* with the use of copper
Cold Spray Competence Group

Industrial Competence

Fundamental Research

Fluid dynamics

H.J. Richter

Spray systems – Equipment - License

P. Richter

Material science

T. Klassen

P. Heinrich

Gas technology

Industry

Linde Gas

A. Kay

Linde
References and Representatives

World-wide references

North America

Europe

Asia and Australia

September 2010
Thank you for your attention