Thermal Spraying

A SURFACE COATING TECHNIQUE

Items
Water plasma spraying
Gas plasma spraying
High velocity oxygen fuel spraying
Electric arc spraying
Flame spraying (wire, rod, powder)

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Thermal Spraying

Our thermal spraying technology utilized in a wide range of industrial fields

Thermal spraying is a technology that uses a combustion flame or electrical energy to fuse various types of materials, forming a coating on the surface of the substrates, and adding a high-quality, high-performance surface covering for a variety of equipment and devices. Thermal spraying is versatile, with application possible on substrates in a wide variety of types and shapes, where coating thickness can be specified from thin films to thick overlays. This technology is heavily used in all types of industrial fields for upgrading and diversification, as well as improving substrates performance, and development of substrates with new functions.

OFIC (OSAKA FUJI Corporation) offers optimal thermal spraying methods developed through many years of experience in thermal spraying technology, including selection of thermal spraying materials, methods, and spraying substrates, while considering every angle, such as application and required functionality. To become a leading company in the field of thermal spray technology, OFIC also actively participates in projects and technological development such as automation using robots, and the state-of-the-art metal thermal spraying, such as plasma thermal spray equipment for use at local sites.

Features of thermal spray technology
Thermal spray technology has various superior features when compared to other surface covering technologies.

- Various materials can be used in surface modification covering (thermal spraying materials) depending on the purpose of modification and application, such as fusible alumina, ceramics such as zirconia, as well as metals and plastics.
- Modification is possible even for large and complex-shaped equipment, down to small parts. Additionally, a wide-variety of coating thicknesses can be selected, from thin films to thick overlays.
- The thermal spray substrate remains comparatively low temperature (200°C or lower, approx.) during spraying, which allows the subject to maintain its organizational structure and physical properties.
- Thermal spraying can be carried out in atmospheric conditions, low-vacuum, or inert gas environments depending on the modification purpose or intended application.

Thermal spraying application process

Thermal spraying application process

1. Product arrival
2. Edge preparation when necessary
3. Degreasign
4. Cleaning
5. Masking
6. Protection of parts not being sprayed
7. Blast
8. Roughening of substrate
9. Thermal spraying
10. Re-fusing heat processing
11. Polishing
12. Machining
13. Thermal spraying left as-is
14. Sealing
15. Final inspection
16. Delivery

Select materials and spraying methods depending on each service condition.
Water plasma spraying

- Perfect for large-format, thick covering applications
- Newly-developed free ceramic molds

Ceramics spraying can reduce costs compared to gas plasma spraying!

- Product: Carbon plating
  - Application: Preventing reaction under high temperatures
  - Size: 300 x 420 x 6 t

- Product: Conveyor pulley
  - Application: Abrasion resistance, corrosion resistance
  - Size: φ800 x 1500 l

- Product: Paper manufacturing roll
  - Application: Abrasion resistance
  - Size: φ800 x 6400 l

Newly-developed free ceramic molds

- WAPLOC form and dimensions

Ceramic parts in various shapes can be fabricated.

General characteristics
- A very high spraying capacity per unit time as high as 50kg at its maximum.
- Thick overlay of a sprayed film about 20mm possible: Control of low substrate temperature at 200℃ or below during the prosecution of work possible.
- Most suitable for a mass and thick overlay spraying of a large member.
- A cheap spraying cost.

Characteristics of OFIC
- OFIC enables to increase coating thickness limit to 20~50mm from 20mm which has so far been its limit.
- OFIC enable to spray even a metal type compound as a material which has so far been limited to oxide type ceramics.

What is “Plasma”?
Plasma is generally said to be fourth state of a substance next to solid, liquid and gaseous states. If the temperature of gas increases beyond its critical temperature, gaseous molecules dissociate into atoms and further electrons are repelled out of atoms to ionize, resulting in a state in which molecules, atoms, (+) ions and (-)electrons exist together. Such a mass of ionized high temperature gases is called Plasma.

The mechanism of this apparatus is devised for a high pressure water current fed into a torch to produce a cylindrical vortex water current. Voltage applied across the carbon cathode and the iron-made rotating anode to forcibly generate a D.C. arc causes the inside surface water of the vortex water decomposition, continuously generating a plasma arc. Being squeezed by the turning cylindrical cater current and increasing its energy density, the plasma arc blows out as a high temperature and high speed stable plasma jet flare affected by the rapid thermal expansion of the plasma. The plasma jet flare, the highest temperature of which reaches as high as about 30,000℃ enable to easily spray even ceramics with a high melting point.

Spraying material:
Alumina, Zirconia (50 magnifications)

Material Chemical symbol Melting point (°C)
Alumina Al₂O₃ 2,050
Spinel MgO-Al₂O₃ 2,100
Alumina/Titania Al₂O₃-TiO₂ 1,860
Mullite 3Al₂O₃-2SiO₂ 1,850
Zircon ZrO₂-SiO₂ 1,700
Gas plasma spraying

It voltage is applied across the tungsten cathode and the copper nozzle anode in the actuating gas such as argon and helium to generate a D.C. arc, the actuating gas dissociates and ionizes, continuously generating a plasma arc. This plasma arc is squeezed by the nozzle and blows out as a plasma jet of an ultrahigh temperature at 15,000°C or above and of an ultrahigh speed. Powders fed into the plasma jet are accelerated as being melted and coats a material. This method enables spraying of high melting point materials such as ceramics. Further it enables formation of sprayed films of quality more superior compared with those obtained by other spraying methods because melted particles are sprayed to substrate at a high speed by Plasma jet. It can also spray various materials.

### General characteristics
- Spraying of all materials including ceramics and general metals possible.
- Formation of sprayed films finer and superior in quality effective heat resistance and chemical corrosion resistance.
- Rare oxidation and deterioration of materials because of the use of an inert gas such as argon.
- Control of low substrate temperature at 200°C or below possible.
- Most suitable for spraying of a small member.

### Characteristics of OFIC
- A portable device enables on-the-spot plasma spraying.
- Spraying of a large construction (building) also possible.

#### Spraying material
- Alumina Zirconia (50 magnifications)

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### Products

**Gas plasma thermal spraying for high-tech coatings**

- **Product:** Hearth roll
  - Application: Build-up resistance
  - Size: ø500 x 2100

- **Product:** Threading-resistant feed roller
  - Application: Abrasion resistance
  - Size: ø30 x 125 l

- **Product:** Walking beam
  - Application: Build-up resistance
  - Size: 210 x 250 x 2800
Hydrocarbon and hydrogen-mixed gas is burned in the internal combustion chamber and the combustion gas is converted into a high temperature ultra-sonic combustion gas jet (Mach 5 or more) through four concentrated nozzles. A powder material fed into the center of the gas jet by nitrogen gas crashes against a substrate as being melted and accelerated inside the nozzle and in the highly concentrated combustion gas jet. Consequently, coatings fine and superior in quality can be formed.

General characteristics
- Formation of coatings superior in quality which are better in their hardness and fineness and more adhesive compared with those obtained by other spraying methods.
- Most suitable for spraying of refractory metal materials (WC-Co).
- Highly efficient in spraying because of its long and highly concentrated gas jet.
- Most suitable for spraying of small members because of its gas jet with a smaller diameter.
- Control of a raw material temperature at 200°C or below possible.
- Small and uniform roughness of a coating surface.

Characteristics of OFIC
- Spraying of cermet such as chromium carbide type materials possible.
- Spraying of a large member also possible.
- Control of coating properties by changing the kind of gas possible.

Products
- Super high-precision coating high velocity oxy-fuel spraying
  - Product: Turbine blade
  - Application: High-temperature oxidation resistance
  - Size: φ1500 x 2100 l

- Product: Bridle roll
  - Application: Anti-slip
  - Size: φ1000 x 2100 l

- Product: Ultrasonic horn
  - Application: Abrasion resistance
  - Size: 50 x 50 x 150, etc.

- Product: Paper manufacturing roll
  - Application: Abrasion resistance
  - Size: φ500 x 6500 l
Arc spraying

Two pieces of spraying materials (wire rod) continuously fed, which are + and - electrodes, respectively, generate arcs at their tips. Molten drops of metals melted by the arc heat are continuously made minute by the air jet and are sprayed on the surface of a substrate.

- **General characteristics**
  - Adhesive strength and bond strength greater than those with flame spraying.
  - High spraying efficiency
  - Formation of a quasi alloy coating by using two pieces of dissimilar metal and alloy wire rods.
  - Spraying by all metals which can be wire rods possible.
  - No deterioration and changes found on materials to be sprayed because of low temperature spraying.
  - Superior oil retaining property and very improved sliding wear characteristic because of pores within coatings.

- **Characteristics of OFIC**
  - Attainment of thick overlay spraying as thick as 20mm.
  - On-the-spot spraying possible.

Flame spraying (wire, rod)

The wirelike or rodlike spraying material inserted through the center hole of the spraying torch is melted by Oxygen-fuel flare. Then being made minute and blown away by compressed air jet from the circumference, it is sprayed on the surface of substrate.

- **General characteristics**
  - No deterioration and changes found on materials to be sprayed because of the low temperature spraying.
  - Spraying of ceramics with a comparatively low melting point possible according to the shape of rods or tubes.
  - Coatings with finer surface roughness and higher hardness obtained with arc spraying.
  - Smaller loss of chrome and carbon compared with arc spraying.

- **Characteristics of OFIC**
  - OFIC has many achievements of rust preventive spraying for aluminum and zinc as the main force of on-the-spot spraying.
Flame spraying (Powder)

The spraying powder material fed into the spraying torch by feed gas through the feed inlet is melted by oxygen-fuel flare and sprayed on the surface of substrate. This spraying method is used especially for spraying a fluxing alloy. It can also spray ceramics and plastics as well as general metals.

● Self-fluxing alloy spraying
A pore-less deposit metal layer is formed by applying a refusing process after the spraying of the self-fluxing alloy powder material according to the above-mentioned gas powder spraying method.

General characteristics
- A low friction coefficient and high wear resistance.
- Corrosion resistance higher than that of the equivalent to high nickel alloys.
- High hardness at high temperatures.
- Does not need a thick padding and gives uniform hardness because of its deposit filling without penetration of a substrate which appears in build up welding.
- Brings added values such as high wear resistance by dispersing carbides and boride.

Characteristics of OFIC
- OFIC enables spraying of even substrate such as cast iron for which a welding method is not suitable.
- On-the-spot spraying possible.
- Spraying of large members also possible.

Products

Flame spraying (powder) – perfect for self-fluxing alloys

- Product: Plunger
  - Application: Abrasion resistance
  - Size: φ125 x 450 l

- Product: Sleeve
  - Application: Abrasion resistance
  - Size: φ70 x 50 l, etc.

- Product: V roll
  - Application: Abrasion resistance/seizure resistance
  - Size: φ200 x 185 l

* Nylon 11, polyethylene, epoxy resin and denatured EVA can be used as plastic spraying materials.
* Refusing process is to combine the sprayed coating with the substrate metallurgically by putting the coating in a semi-molten state at 1,000~1,100°C. Boron and silicon in the alloy reduce in the coating and then change to sticks which rise to the surface, consequently making the structure of the coating pore-less. At the same time boron and carbon in the alloy precipitate as boride and carbide, resulting in improving the wear resistance.
<table>
<thead>
<tr>
<th>Classification</th>
<th>Material name</th>
<th>Typical composition</th>
<th>Thermal spraying method</th>
<th>Gas</th>
<th>Electrical</th>
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<td>Zinc</td>
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<tr>
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<td>Aluminum</td>
<td>99.7-99.99%</td>
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<td>Low C</td>
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<td>High-carbon steel [plain wire]</td>
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<td>Stainless steel</td>
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<td>Fe-Cr series of amorphous alloy</td>
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<td></td>
<td>Brass</td>
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<td>Aluminum bronze</td>
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<td>Nickel-aluminides</td>
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<td>Monel</td>
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<td>Stellite #6</td>
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<td>MCrAlY alloy</td>
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<td>METCO 15E equivalent (5 types)</td>
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<td>Co-based</td>
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<td>Others</td>
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<td>Yttria (oxidized yttrium)</td>
<td>Y</td>
<td>○</td>
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</table>

* indicates that no air passes through pores.
Main thermal spraying materials and coating properties - 2

Classifications of thermal spraying methods

- Flame spraying [wire, rod, powder]
- High velocity oxy-fuel spraying [powder]
- Jet Nozzle
- Plasma spraying [powder]
- Water plasma (Reduced-pressure plasma)
- Petrol thermal spraying [powder]
- Arc spraying [wire]
- Electric

Thermal spraying rustproofing effects due to salt water spray testing

<table>
<thead>
<tr>
<th>Test specimen</th>
<th>1,000 hours</th>
<th>2,000 hours</th>
<th>3,000 hours</th>
<th>6,000 hours</th>
<th>Comments</th>
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<td>Al thermal spraying (80,160,200 μm)</td>
<td>•</td>
<td>•</td>
<td>•</td>
<td>•</td>
<td>•</td>
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<tr>
<td>Same as above, silicon or epoxy resin-nanocoating treatment</td>
<td>•</td>
<td>•</td>
<td>•</td>
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<tr>
<td>ZrN alloy thermal spraying (50,100,120 μm)</td>
<td>•</td>
<td>•</td>
<td>•</td>
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<tr>
<td>Same as above, silicon or epoxy resin-nanocoating treatment</td>
<td>•</td>
<td>•</td>
<td>•</td>
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<tr>
<td>Inorganic zinc-rich paint (40,75 μm)</td>
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<td>Thermal spray zinc plating (30 μm)</td>
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* Explanation of icons in the comment section (weight change due to salt water spray testing)
• Least weight change
• Significant weight change
• Minimal weight change
• Most weight change
• Moderate weight change

Thermal spray covering high-temperature hardness

Comparison of thermal spray coating abrasion-resistant properties

The relationship between Al₂O₃ coating thickness and voltage resistance

WAPLOC DATA

Table: Relationship between Al₂O₃ coating thickness and voltage resistance

<table>
<thead>
<tr>
<th>Voltage resistance (KV)</th>
<th>0</th>
<th>0.25</th>
<th>0.5</th>
<th>0.75</th>
<th>1</th>
<th>1.25</th>
<th>1.5</th>
<th>1.75</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coating thickness (μm)</td>
<td>0</td>
<td>0.2</td>
<td>0.4</td>
<td>0.6</td>
<td>1</td>
<td>1.2</td>
<td>1.4</td>
<td>1.6</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Coating (μm)</th>
<th>0</th>
<th>0.2</th>
<th>0.4</th>
<th>0.6</th>
<th>1</th>
<th>1.2</th>
<th>1.4</th>
<th>1.6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Voltage resistance (KV)</td>
<td>0</td>
<td>0.25</td>
<td>0.5</td>
<td>0.75</td>
<td>1</td>
<td>1.25</td>
<td>1.5</td>
<td>1.75</td>
</tr>
<tr>
<td>Coating thickness (μm)</td>
<td>0</td>
<td>0.2</td>
<td>0.4</td>
<td>0.6</td>
<td>1</td>
<td>1.2</td>
<td>1.4</td>
<td>1.6</td>
</tr>
</tbody>
</table>
OFIC has accumulated a wide range of technical expertise over many years of manufacturing, machining and repairing steelmaking equipment. The essence of this expertise is brought together at Amagasaki Factory. Starting with materials procurement, Amagasaki Factory uses technology such as machining with large machine tools, finishing with precision machinery, special welding: automatic hardfacing powder plasma welding, general welding. Its integrated work system spans all processes from inspection through assembly and adjustment. Working closely with OFIC’s engineering departments, the factory draws on its comprehensive lineup of technical expertise to precisely meet various needs ranging from equipment design to manufacture and installation.

In 1969, Omigawa Factory moved to a massive site of around 22,000 square meters that OFIC had acquired in Chiba’s Omigawa Industrial Park which located in Chiba Prefecture. After initially working on pressure vessel fabrication and overlaying, the site steadily expanded its activities by constructing a specialized machining plant, a plant for large roll overlaying and large pressure vessel fabrication, and a thermal spraying plant. In 2004, Omigawa Factory installed technology for manufacturing small forged hardened steel rolls.

Through overlay welding and thermal spraying technologies, technological development for functional deposit forming with various qualities such as corrosion resistance, wear resistance, scoring resistance and impact resistance are promoted. Using the technologies that we have developed, we greatly contribute to advanced product development in various fields.

Thermal spraying is a surface covering and treatment technique that deposits a film of melted materials such as ceramics, cermets, metals or resins onto a surface material to make it more wear-heat- or corrosion-resistant, or improve properties such as electrical insulation. Widely used in industrial fields requiring advanced functions, thermal spraying is used to make products such as communication satellites, high-rise steel structures, industrial machinery parts, electronic devices and consumer appliances. Senboku Factory specializes in advanced thermal spraying technologies, and assists Amagasaki Factory as a major production base for large products manufactured with thermal spraying.

This production base for thermal spraying leads our generation in new technical development.