Solutions Flash
Laser cladding repairs for aerospace and industrial gas turbine applications
Today’s situation

Older repair technologies are constantly being challenged by new processes that offer benefits in performance, efficiency and cost. Repairs to gas turbine components require cost-effective processes, quick turn-around times and robust results. Laser cladding is a welding technology that is often used to replace GTAW (Gas Tungsten Arc Welding). Laser cladding offers these benefits over older, conventional welding methods:

- **Very low heat input and low distortion**, which is essential for parts with tight tolerances where substrate distortion is problematic
- **Large number of materials available** to match substrate performance in gas turbine applications, including wear and corrosion
- **Molecular bonding** resulting in better adhesion that out-performs mechanically bonded processes
- **Chemistry and hardness** are retained without need for additional coatings
- **Rapid cooling rate** ensuring faster part throughput
- **Lower stresses on substrates** due to lower heat input
- **Environmentally-friendly** as parts that were considered “scrap” can now be repaired for a fraction of the cost of a new part.

The Oerlikon Metco solution

Oerlikon Metco, the leading supplier of Laser Cladding solutions for IGT and Aero component repair applications, has developed a portfolio of laser cladding materials. Oerlikon Metco’s materials have been designed such that the laser deposits are optimized for the many varied repairs on gas turbine components.

Moreover, Oerlikon Metco can provide a complete solution package, that either includes the materials and the spray system, or services to clad customer-supplied parts. In addition, we have expert material technologists to consult on specific requirements.

With more than 25 years of laser cladding experience for turbine engines, Oerlikon Metco has the experience and competence to provide repairs that our customers can have complete confidence in the solutions we provide.
Solution description and validation

1. The laser cladding process

- The laser beam is defocused on the workpiece with a selected spot size
- Metal powder as the filler material is transferred with an inert carrier gas into the melt pool
- The laser beam and the powder nozzle are moved over the workpiece surface producing single tracks, layers and build ups

2. Comparison of laser cladding to competing processes

<table>
<thead>
<tr>
<th>Overlay Process</th>
<th>Improvement Using Laser Cladding</th>
</tr>
</thead>
<tbody>
<tr>
<td>PTA Welding Powder and Wire</td>
<td>Reduced heat input, Lower dilution</td>
</tr>
<tr>
<td>GMAW / GTAW Solid and Cored Wire</td>
<td>Reduced heat input, Lower dilution</td>
</tr>
<tr>
<td>Thermal Spray Combustion / HVOF / EAW</td>
<td>Lower porosity, Metallurgical bonding, Higher deposit efficiency</td>
</tr>
<tr>
<td>Thermal Spray Spray and Fuse</td>
<td>Reduced heat input, Lower porosity, Higher deposit efficiency</td>
</tr>
</tbody>
</table>

Laser Cladding

Improved Process vs. GMAW / GTAW

HVOF: High Velocity Oxygen Fuel Spray; EAW: Electric Arc Wire Spray; GMAW: Gas Metal Arc Welding (MIG); GTAW: Gas Tungsten Arc Welding (TIG)
3. Laser cladding applications

3.1 Blade tips with encapsulated CBN
Blades that run against ceramic abradable materials used in the hot section of the engine for clearance control are generally tipped. The tipping materials consists of a matrix materials that is matched to the composition of the blade and a cutting material, such as Cubic Boron Nitride (CBN). The CBN not only provides a cutting medium in the case of incursion into the ceramic abradable, but it is also lubricious. These properties protect the blade from damage.

The use of laser cladding to apply the blade tipping material is more efficient and ensures a homogeneous distribution of the CBN within the matrix.

3.2 Turbine blade tip dimensional restoration
Using a contour scan to bring a blade back to dimensional specifications via a laser cladding weld repair.

Left: Blade tip being repaired using laser cladding. Right: Structurally sound laser cladding weld build up of 8 mm
3.3 Seal rings
Seal rings manufactured using laser cladding (also referred to as Direct Metal Deposition or DMD) can have a large cost savings compared to profile rolling and butt welding.

Strategies to repair substantial features of seal rings are also performed, thereby salvaging components that would have once been scrap. Areas repaired using laser cladding include sealing faces, knife edges and snap diameters.

3.4 Knife edges
Thin-walled areas, such as knife edge seals can be successfully restored thanks to the low heat input that results in a minimal heat affected zone and the low dilution offered by the laser cladding process. The near-net shape of the build-up minimizes the finishing effort, saving time and cost for post-deposition processing.

3.5 Thin walls
Thin-walled areas are effectively restored using laser cladding, without part distortion and have a minimal heat-affected zone.

3.6 Multi-layer build up
Multiple layers of laser cladding can be used to repair components where thicker deposits are needed. Hence, laser cladding is an excellent choice to restore heavily damaged areas on many types of components.

3.7 Feature additions
For some applications, laser cladding has proven to be a cost-effective and technologically flexible process to add structural features to a component. For example, laser cladding has been used to create a grid pattern on turbine hot section seal segments that helps to anchor and enhance thermal barrier coatings.
4. Laser cladding materials

Oerlikon Metco offers a range of materials designed for laser cladding applications. Oerlikon Metco engineers and manufacturers our laser cladding materials in house using state of the art facilities and quality control. Our most popular laser cladding materials are listed in the table below.

4.1 Superalloys, steels and carbide materials

<table>
<thead>
<tr>
<th>Product Name</th>
<th>Material Type</th>
<th>Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metco 1700A</td>
<td>Hastelloy C276</td>
<td>Sour gas and halide corrosion resistance</td>
</tr>
<tr>
<td>Metco 1625B, Metco 1625F</td>
<td>Inconel 625</td>
<td>Corrosion at extreme conditions, dimensional restoration</td>
</tr>
<tr>
<td>Metco 1220A, Metco 1220B</td>
<td>Stellite 6</td>
<td>Resist siezing, galling, abrasion, adhesion and erosion; resistant to thermal oxidation and oxidizing acids</td>
</tr>
<tr>
<td>Metco 1221A</td>
<td>Stellite 21</td>
<td>Cavitation and galling resistance with superior corrosion resistance; deposits nearly 100% dense</td>
</tr>
<tr>
<td>Metco 1223A</td>
<td>Ultimet</td>
<td>Wear and corrosion resistance; excellent work-hardening properties</td>
</tr>
<tr>
<td>MetcoClad 718</td>
<td>Inconel 718</td>
<td>Elevated corrosion and high strength at high temperatures, dimensional restoration</td>
</tr>
<tr>
<td>MetcoClad 316L</td>
<td>316L Stainless Steel</td>
<td>Corrosion, creep and rupture stress resistance</td>
</tr>
<tr>
<td>MetcoClad 52052</td>
<td>Spherical tungsten carbide and self-fluxing NiCr matrix</td>
<td>High hardness for high wear and erosion resistance</td>
</tr>
<tr>
<td>Metco 50075A</td>
<td>Spherical tungsten carbide</td>
<td>Hard face constituent for blending in customer’s matrix material, high hardnes for wear and slurry erosion</td>
</tr>
</tbody>
</table>
4.2 Laser clad superalloys deposit examples

**Metco 1220B** (composition similar to Stellite 6)

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Metco 1221A is a high-temperature material that can be used for repair of gas turbine compressor blades that is similar to Stellite 21.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hardness</td>
<td>48 to 51 HRC</td>
</tr>
<tr>
<td>Abrasion resistance</td>
<td>65 to 75 mm³ vol. loss (ASTM G65-B)</td>
</tr>
<tr>
<td>Layer deposition</td>
<td>Multiple layers are possible</td>
</tr>
<tr>
<td>Cracking</td>
<td>Crack-free deposition achievable</td>
</tr>
<tr>
<td>Service features</td>
<td>Low frictional coefficient</td>
</tr>
<tr>
<td></td>
<td>Good combined resistance to abrasion and impact</td>
</tr>
<tr>
<td></td>
<td>Excellent cavitation and erosion protection</td>
</tr>
<tr>
<td></td>
<td>High corrosion and oxidation resistance</td>
</tr>
<tr>
<td></td>
<td>Temperature up to 800 °C (1470 °F)</td>
</tr>
</tbody>
</table>

**Metco 1700A** (composition similar to Hastelloy C276)

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Metco 1221A is a high-temperature material that can be used for repair of gas turbine compressor blades that is similar to Stellite 21.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hardness</td>
<td>27 to 72 HRC</td>
</tr>
<tr>
<td>Abrasion resistance</td>
<td>85 to 90 mm³ vol. loss (ASTM G65-B)</td>
</tr>
<tr>
<td>Layer deposition</td>
<td>Multiple layers are possible</td>
</tr>
<tr>
<td>Cracking</td>
<td>Crack-free deposition achievable</td>
</tr>
<tr>
<td>Service features</td>
<td>Highly versatile corrosion resistance</td>
</tr>
<tr>
<td></td>
<td>Excellent resistance to stress corrosion cracking</td>
</tr>
<tr>
<td></td>
<td>Excellent resistance to acids</td>
</tr>
<tr>
<td></td>
<td>Strong resistance to salts</td>
</tr>
<tr>
<td></td>
<td>Good resistance to sulfide-induced stress cracking</td>
</tr>
<tr>
<td></td>
<td>Outstanding resistance to crevice and pitting corrosion</td>
</tr>
</tbody>
</table>
4.2 Titanium materials

Titanium is widely used in aerospace for its high strength-to-weight ratio, low density and corrosion resistance. A very thin, stable titanium oxide passive surface layer naturally forms on all titanium material giving titanium its strong corrosion resistance. However, this very strong affinity for oxygen combined with the powder particles’ high surface area to volume ratio makes titanium powder difficult and relatively expensive to manufacture.

The two main processes for titanium powder manufacture are the hydride-dehydride (HDH) process and the atomization process, which is the less expensive route that produces an angular/blocky particle morphology. The atomization processes, being somewhat more expensive, produces powders with a spherical morphology.

The choice of powder manufacturing process has a distinct effect on the end result and can be critical to application success. Traditional titanium laser cladding processes have previously used atomized titanium powders and systems enclosed inside a vacuum chamber to prevent excessive oxidation of the titanium weld pool. Recent developments in laser cladding technology have demonstrated successful titanium laser cladding using a duel-gas shield approach thus eliminating the need for a vacuum chamber. [1,2]

4.2.1 Oerlikon Metco’s titanium portfolio for laser cladding

Oerlikon Metco currently offers both angular and spherical CP Ti and Ti-6Al-4V powders for laser cladding applications. Our standard products are shown in tables below, however custom particle sizes are available upon request.

<table>
<thead>
<tr>
<th>Product Name</th>
<th>Chemistry</th>
<th>Grade</th>
<th>Particle Size (µm)</th>
<th>Morphology</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metco 4012A</td>
<td>CP Ti</td>
<td>Grade 1</td>
<td>-106 +45</td>
<td>Blocky (HDH process)</td>
</tr>
<tr>
<td>Metco 4013A</td>
<td>CP Ti</td>
<td>Grade 2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Metco 4030C</td>
<td>Ti 6Al 4V</td>
<td>Grade 5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Metco 4032A</td>
<td>CP Ti</td>
<td>Grade 23</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Metco 4023B</td>
<td>CP Ti</td>
<td>Grade 1</td>
<td>-106 +45</td>
<td>Spherical (atomization process)</td>
</tr>
<tr>
<td>Metco 4024B</td>
<td>CP Ti</td>
<td>Grade 2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Metco 4031A</td>
<td>Ti 6Al 4V</td>
<td>Grade 5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Metco 4033A</td>
<td>Ti 6Al 4V</td>
<td>Grade 23</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### 4.2.2 Titanium deposit examples (current powder portfolio)

Oerlikon Metco working in collaboration with the ETH Zürich have successfully applied angular and spherical commercially pure (CP) titanium and Ti-6Al-4V alloy powder in atmosphere (no vacuum chamber) as shown in the following images.

![Single layer of a titanium clad deposit using HDH titanium powder without vacuum chamber.](image1)

![Four layers of titanium clad deposits without vacuum chamber.](image2)

### 4.2.3 New titanium powder materials

Oerlikon Metco growing portfolio of titanium powders is designed to meet the needs of the market. Currently, we are developing additional titanium alloy powders manufactured using the more cost-effective HDH process. When released to the market, these products will be available in high volumes and competitively priced.

Samples of these angular titanium alloy powders can be requested from your Oerlikon Metco Account Representative in a standard particle size distribution of -106 +45 µm and designed to meet standard wrought chemistry specifications. Most of these alloy powders have already been successfully tested using laser cladding without any vacuum chamber.

### Coming Soon | In Development
---|---
Ti 10V 2Fe 3Al (Ti 10 2 3) | Ti 6Al 2Sn 4Zr 2Mo (Ti 6 2 4 2)
Ti 15Mo 3Nb 3Al (Ti 21S) | Ti 15V 3Cr 3Sn 3Al (Ti 15 3 3 3)
Ti 3Al 8V 6Cr 4Mo 4Zr (Ti Beta C) | Ti 5Al 2Sn 4Mo 2Zr 4Cr (Ti 17)

![Four layers of a titanium clad deposit using angular/blocky Ti 15V 3C 3Sn 3Al powder without vacuum chamber.](image3)
5. **Laser cladding offerings**

5.1 **Materials and application equipment**
As the worldwide leader in surface solution technologies, Oerlikon Metco offers customers flexibility for their coating implementation. Oerlikon Metco can provide the laser cladding materials, or a complete coating facility solution that consists of the laser cladding materials and state-of-the-art, efficient, laser clad systems that are custom-designed for the components to be coated. We can also provide technology transfer that includes training and support for optimal and consistent processing results.

5.2 **Laser cladding from Metco Coating Services**
However, not all customers desire such a solution. Therefore offer expert laser cladding application services through our network of worldwide service centers. These service centers are well-respected for their attention to detail and quality of production.

We use the most modern techniques and processes at our laser cladding facility to restore aerospace and IGT components, including:
- In-house laboratories for repair investigation and metallography
- Expert knowledge in materials combinations and process control
- CAD-enabled processing
- Temperature control support
- Active cooling support
- Extensive experience in aerospace and IGT requirements, including advanced substrate compositions and difficult material combinations
- Highly experienced team for the entire process from initial consultation through processing, quality control and post-service support

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**Metco Coating Services process solution chain**

**Design**
- 3D-design component
- 3D-design tools

**Strategy**
- Offline programming of coating strategy

**Process**
- Offline process simulation and optimization

**Translation**
- Translation into machine-readable program

**Production**
- Online application and laser cladding production of actual parts

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Make or buy: It’s your decision. Use our expert laser cladding services or purchase tailored laser cladding materials and equipment technology.

CAD-enabled processing is just one of the ways we ensure reliable and reproducible deposition results with our laser cladding services.
Customer Benefits

**Excellent Value**
- Our MetcoClad™ portfolio of powder materials are designed to meet the exacting requirements needed for laser cladding applications
- Our customers benefit from our worldwide support, from pre-sale consultation through on-going post-sale support services

**Experience**
- Oerlikon Metco has over 25 years experience with laser cladding and a highly experienced team
- Oerlikon Metco has been a trusted supplier of materials for demanding industries that include aerospace and power generation for more than 85 years
- Our laser cladding services are active in several industries including gas turbine component repair
- Our complete portfolio of laser cladding powders ensures the right material choice, whether for dimensional restoration, wear resistance and/or corrosion resistance
- We continually expand our portfolio of laser cladding materials to meet the expectations of our customers
- Our laser cladding systems build on our long history of customization and integration, tailored to customer needs.

**Efficient**
- Laser cladding is an excellent process for repair and dimensional restoration of components, saving costs and valuable resources
- Forged parts that were manufactured less than net size or shape can be dimensionally corrected using laser cladding, saving cost and reducing scrap
- Solutions available for customers who wish to apply coatings in-house or coating service solutions for customers who prefer to out-source
- Our laser cladding services use advanced processing techniques, in-house quality laboratories

**Effective**
- Laser cladding is a well-established process for the repair and dimensional restoration of gas turbine components, allowing components that would have been scrapped to be put back into service
- Laser cladding is increasingly used as a low temperature process to apply functional deposits on advanced substrates used in today’s gas turbines
- Displaces traditional high heat welding process with minimal or no substrate deformation
- Wide choice of materials allows reproducible deposits to meet specific operating requirements, and can even improve on the original component surface functionality
- Oerlikon Metco’s state-of-the-art materials technology and manufacturing capabilities allow us to develop new laser cladding materials for specific applications
References
