Laser Cladding for Turbines

Blade profile repair and enhancement using TRUMPF TruDisk laser technology

10/20/10
“Throughout the turbine market, laser cladding is an expanding market. New technologies have enabled new procedures in the build up of leading edge profiles, tips and “Z” notches.

This technology is by no means new. It has been used commercially for the better part of 20 years.

Refinements in laser technology, motion systems, vision systems and positioning software have enabled laser cladding to produce a near net shape or in some cases a cladding surface that meets requirements as clad. European manufacturers have been using this technology for a while.”

- Steve Roy, Manager, Hayden Laser Services

**Key Features of Laser Clad Overlays**

- Highly accurate and repeatable
- Significantly reduced impact on substrate
- Flexible and adaptable
- Simpler and more cost effective processing
Laser cladding hardware is completely automated and typically programmed directly from a solid model of the component to be clad. Welding bead contours are placed directly onto the model's surfaces, ensuring perfect alignment of both contour length and placement, as well as processing orientation with respect to the surface.

Alternately, through-the-lens monitoring allows component processing to be taught into the motion control system from an actual piece. In this way, weld contours can be quickly customized for repair and restoration of unique features.
Automation of every aspect of the cladding process, including motion control, laser power and focus, and powder delivery ensures that the last part of a batch is processed identically to the first.

Operator intervention is limited only to loading and unloading of parts and ensuring raw materials supplies are adequate. All other aspects of processing are software controlled, including extensive fault- and process-monitoring. If any uncontrolled variation in process parameters is detected, processing is halted until the problem is corrected.

Monitored parameters include:

- Real laser power
- All process gas flows and pressures
- Process cooling
- Safety system status
- Actual tool position and laser focus
- Powder availability and feed rate
The software for each part number to be processed includes commands that directly specify laser power, gating frequency, and focus spot size, shielding and powder feed gas flows, powder feed rates, and processing speeds. Each of these parameters can be varied within the execution of a program, including the selection of powder feeders and feed rates, so that gradated and layered coatings can be applied within one program.

Since the program controls every aspect of the process, parts are consistent both within the batch and from batch to batch, day to day, and year to year.

Flexible software also makes it simple to move from one part number to another, and back again, usually in a matter of minutes.
The primary benefit of laser processing remains the unique metallurgical characteristics of laser clad overlays.

In addition to the robustness of the process, in terms of stability and accuracy, overlays applied by laser cladding demonstrate physical characteristics that can outperform other welding methods in a wide range of applications.

The method also allows for applying a broad range of materials to most metallic substrates. Very few materials have proven difficult to apply, and most substrates behave favorably, when welded by laser.
Rapid solidification often yields a denser grained, harder overlay

There is minimal dilution of overlay material by the substrate
- Typical dilution zone for a 1mm thick overlay is less than 0.2mm
- Surface properties of the overlay are typically as needed after the first pass. There is often no need for multiple passes, reducing heat input, residual stress, and extensive post-processing

Very low heat affected zone, compared to other welding methods
- Typical HAZ for a 2mm thick overlay is less than 1mm
The low heat input that allows for low dilution and rapid solidification also ensures that distortion of the base material and residual stresses within the overlay are minimized. As a result, thin components and pieces with very fine tolerances can be welded with little or no risk of adverse dimensional effects.

This can be especially useful for restoration of damaged components that are already at finished size in most locations. Worn or mis-machined areas can be built up with laser cladding and machined back to finished dimensions without interfering with nearby features.
Turbines for aerospace and power generation are ideally suited for repair, fabrication, and enhancement by laser cladding. The components of turbines are at once highly machined and complex in shape, but also produced and used in high quantities in an environment susceptible to wear and damage. Laser applied overlays are well suited to providing protection from wear and corrosion in service, as well as repairing and restoring worn or damaged components returned from the field. The economic benefits can be seen in terms of longer component life and lower overall rates of scrap due to greater rework opportunities.

Current applications include

- Airfoil tip restoration
- Profile repair
- Abradable seal fabrication
- Crack repair and salvage
- Leading edge protection and restoration
- Erosion and cavitation prevention
- Z-Notch and squealer tip repair
Typical Application: Repair of leading edge by cladding

- Excavate damaged area by milling a consistent repair geometry
- Clad machined area according to manufacturing plan
- Finish by belt grinding, hand polishing, or laser
- Material selection can be same as parent, or better for longer life
Flexibility...

Unlike coaxial nozzles that use gravity to assist the convergence of powder at the weld pool, multi-jet laser cladding nozzles can operate at virtually any angle or orientation. As a result, complex geometries that require extensive articulation of the cladding head can be welded easily and uniformly.

Working in concert with the offline programming suite and motion control system, the cladding nozzle is a key component in producing a high-quality, accurate weld overlay on any surface geometry, no matter how challenging.
Flexibility...

Automation ensures accuracy and repeatability, and it also provides an unmatched degree of flexibility. By working with multi-axis machine tools and three dimensional programming, custom tooling requirements are minimized, and there is little specialization needed for individual part numbers or component types.

Changing from one blade style to another, or from turbine blades to shrouds is largely a matter of selecting a different program for execution and ensuring the proper feedstock is in the powder feeder.

Since the program specifies all aspects of part processing very little is left to operator intervention or error.
Alternative Blade Repair Methods

- Manual TIG or other welding repair, hand finish
- Electron beam attachment of replacement section
  - Premachine to remove uniform blade section
  - Electron beam weld replacement blade section
  - Heat treat for stress relieving
  - X-Ray for examination of bonding integrity
  - Hand grinding to blend insert with airfoil profile

- Brazing of profiled insert over damaged area
  - Premachine to accommodate insert placement
  - Manually torch braze or furnace fuse insert in place
  - Torch test or X-Ray to ensure adequate wetting
Case Study - Laser Versus EB Weld Repair, 120 Blades

OLD PROCESS: EB Weld, Grind
- Premachine
- EB Weld
- Heat Treat
- X-Ray
- Straighten
- Grind/Polish

NEW PROCESS: Laser Clad, Laser Polish
- Premachine
- Laser Weld
- Laser Polish
## Case Study - Laser Versus EB Weld Repair, 120 Blades

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<thead>
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<tbody>
<tr>
<td></td>
<td>days</td>
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<tr>
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Typical tolerances:

Overlay Thickness: +/- 0.005"

Heat Affected Zone: < 0.030"

Dilution Zone: < 0.020"

Blade Distortion (lean/length): < 5%

Polished Surface Finish: < 50 Ra, microinch
The demands for both high quality and low cost require innovative solutions to old problems. Forward thinking, with an open mind, is required to advance production standards. Sometimes, it takes more than that.

We, in the laser community, are always striving to improve manufacturing processes. We can only hope that these efforts are well received, and we hope that our enthusiasm is matched in the manufacturing world.

- S. Roy