

# New Systems for Laser Cladding

## Laser surface modifications in steel industry

Components used in the manufacture of steel strip work in exceptionally aggressive environments and have to withstand service at high temperatures in corrosive atmospheres under mechanical wear and frequent and heavy impact loading. Conventionally, components that are subject to high wear or corrosion have often been manufactured from rich chemistry steels or hardfaced using submerged arc clad martensitic stainless steels to increase their campaign life and therefore maximise line throughput by extending maintenance intervals without any sacrifice to product quality.

Martensitic stainless steel (MSS) welded alloys generally have good wear and corrosion characteristics; however, they are not suitable for severe metal on metal abrasion and also lose their mechanical and corrosive properties at high temperatures. Arc welded MSS alloys also suffer from weld sensitisation in grain boundaries in the Heat Affected Zones (HAZ) whereby chromium carbides are precipitated, leaving the surrounding

areas depleted in chromium. These areas are therefore susceptible to localised corrosion.

Thermally sprayed coatings are also in wide spread use throughout the steel industry due to their flexibility in the types of alloys and Metal Matrix Composites (MMC) which can be applied. However, their mechanically bonded interfaces have relatively low strength (unless post spray fusing is employed) limiting their practical use in an environment with very heavy impacts.

In 2009, a system was built in Port Talbot in the United Kingdom in an attempt to develop laser cladding for coating critical works components to increase their service lifetime. In the rolling mills of the steel industry different rolls of 0.3 to 3.5 meters in length are needed. Laser clad coatings have been proven to extend the lifetime of components by up to 6× (Fig. 2).

Since the installation of the laser cladding system in Port Talbot, the process has been developed and numerous Nickel Cobalt and Iron based materials alloys have been assessed, in terms of microstructure, mechanical properties, wear and corrosion



FIGURE 1: Laser cladding using an off-axis nozzle.

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resistance. Detailed process development is required to tailor the coating properties for each application within the steel works (Fig. 3).

The initial results from line trials were extremely encouraging whereby components that were laser clad, obtained unprecedented wear and corrosion performance. As such it was decided to build a production machine to cope with the anticipated demand.

### Laser cladding process offers significant benefits

The laser cladding process is a method of hardfacing which can be used to increase the wear / corrosion / impact performance of metallic components. The process utilises a precisely focussed high power laser beam to create a weld pool into which a metallic



**FIGURE 2: The production laser cladding facility at Tata Steel Strip Products UK.**

powder is applied. The powder is carried by a stream of inert shielding gas and is blown coaxially through the laser beam.

The accurate nature of the laser beam allows fully dense cladding with minimal dilution (< 5 %), yet with a perfect metallurgical bond. Numerous coatings can be applied, the composition of which can be designed to combat the failure mechanisms associated with each component.

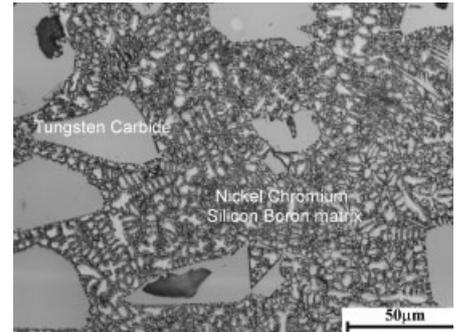
One of the major benefits associated with laser cladding is the ability to finely control the heat input. This allows the ability to deposit a two phase Metal Matrix Composite structure, namely:



**FIGURE 3: The Precitec YC52 cladding head with a co-axial nozzle.**

- **A matrix** – typically a nickel based alloy. This matrix provides toughness, ductility, and impact resistance whilst being wear resistant at elevated temperatures.
- **A reinforcing hard phase** – typically a tungsten carbide but can also be titanium carbide, chromium carbide etc.

The fine control of the heat input allows the matrix to be completely melted and alloyed to the substrate surface, whilst at the same time, the ceramic particles remain unmelted and are distributed evenly through-



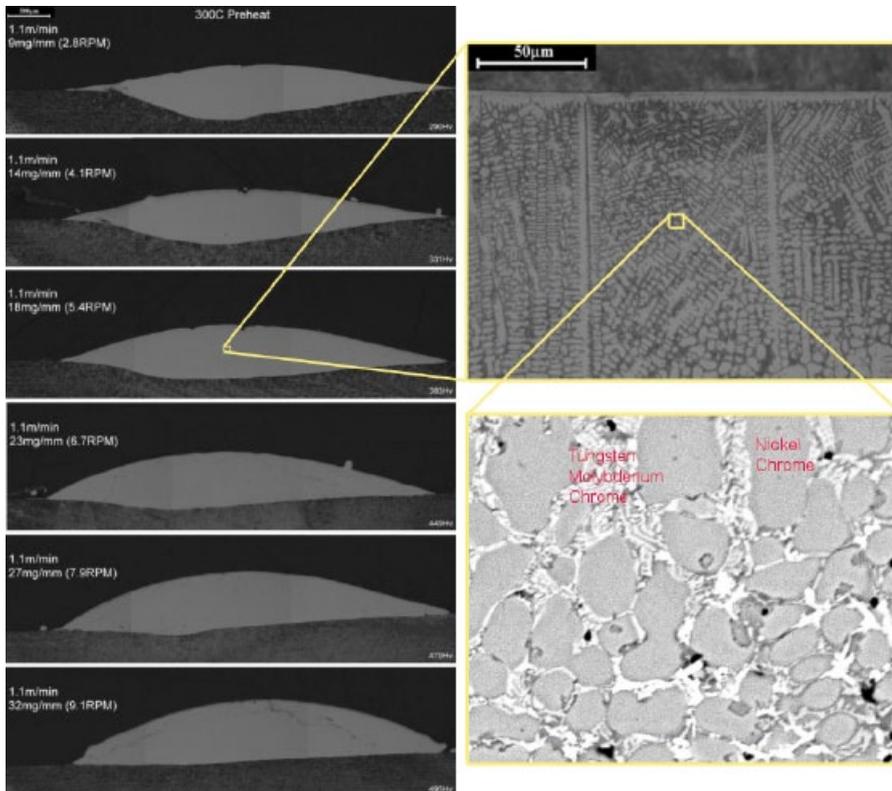
**FIGURE 4: Laser clad micrograph illustrating a typical deposit of Tungsten Carbide in a NiCrSiB matrix.**

out the matrix (Fig. 4) giving an extremely wear and impact resistant coating. The ratio between the hard phase and matrix can be adjusted according to the service conditions, i.e, greater hard phase fraction for greater wear resistance, and less hard phase for greater impact resistance.

Other benefits of the process include:

- Minimal heat input and therefore fast cooling rate with very fine microstructures and negligible distortion.
- The ability to achieve the desired coating chemistry in the 1st layer due to the minimal dilution.
- Ability to produce hardface coatings with exceptional surface finish (possibility of coating rolls and installing without machining).
- A full metallurgical bond with the substrate, unlike all other low heat input spraying processes (HVOF, Cold Spray, D-Gun etc.).

Whilst there are numerous parameters involved in laser cladding, a particularly criti-



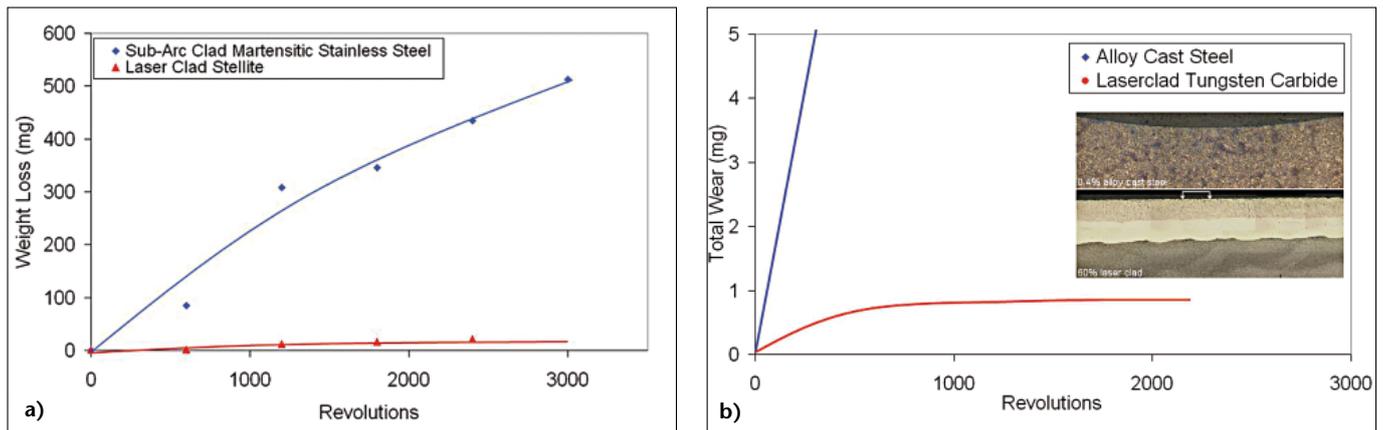
**FIGURE 5: Transverse sections of a NiCrWMo alloy illustrating the dilution as a function of the powder flow rate; a higher magnification light microscopy image detailing the dendritic structure; and a high magnification SEM image illustrating the extremely fine cellular dendritic structure of the same alloy.**

## THE COMPANY

**Precitec GmbH & Co. KG**  
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Precitec is a specialist supplier of highly sophisticated laser systems for material processing. The products are well-known for their reliability and industrial suitability. For laser joining Precitec offers a comprehensive range of quality monitoring systems which can be easily integrated into all industrial standard plant concepts. Various processing heads with integrated sensor systems for non-contact seam tracking and process control are also available for all established types of laser.

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**FIGURE 6:** a) Room temperature sliding wear test of Laser clad tungsten carbide vs. high carbon alloy cast roll steel. The micrograph insert illustrates the 'wear scar' generated during the test. A negligible wear scar was produced on the tungsten carbide. b) High temperature (700 °C) sliding wear test of laser clad Stellite 6 vs. submerged arc clad martensitic stainless steel (as currently applied to hardfaced HSM and Continuous Caster rolls in CSP).

cal parameter is the powder mass flow rate. Once the optimum laser spot diameter, cladding speed and laser power have been identified for a particular application, the powder mass flow rate can be used to control the clad thickness, hardness and dilution as shown in Figure 5 where an increasing powder flow rate can be seen to effectively control the dilution.

Once the optimum parameters have been identified for the single track bead-on-plate weld, mass area coverage is achieved by producing overlapped tracks. The amount of overlap then determines the coating thickness can range from 0.3 mm to 3.0 mm in a single pass.

To demonstrate and quantify the potential benefits of laser cladding versus conventional hardfacing techniques, a number of samples of both laser clad and submerged-

arc clad were produced and wear tested by Tata Steel RD&T at Sheffield University, UK. Results of wear tests carried out at low and high temperatures are reproduced in Figures 6a and b respectively.

As can be clearly seen, the laser cladding process can offer significant improvements in wear resistance over standard materials and hardfacing techniques.

### The production laser cladding facility

Machine tools capable of laser cladding can be purchased directly from suppliers in Europe and America, however, it was decided that a bespoke production laser cladding machine would be built by Tata Steel engineers. The system is based on a Laser Line fibre coupled diode laser with a Precitec YC52 cladding head and a Metallisation mass flow controlled powder feeder. The system is controlled by Fanuc robot with an additional 7th axis for rotating cylindrical parts up to 6 tonne in weight and 3.5 m long (Fig. 7).

The operation of the machine is controlled through a touch screen HMI. The system was designed to operate in an autonomous manner, whereby; the robot is capable of automatic programming. This is achieved by the incorporation of a distance measurement laser that determines geometry of the component, the start and stop locations, and also the laser head standoff distance. This ensures that the state-of-the-art process can be operated with very little training. Detailed monitoring ensures that the process is stable whilst an automatic stop and retract function prevents damage in the event of an unexpected interruption.

The laser cladding process has shown substantial benefits for increasing the critical lifetime of works components in the steel industry, and with the advent of high power diode laser systems and dedicated laser cladding nozzles, a robust cladding process is now far simpler to design and integrate for hardfacing applications.

## THE COMPANY

### Tata Steel Strip Products UK

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Tata Steel is one of the world's most geographically diversified steel producers, with operations in 26 countries and commercial offices in over 50 countries. With 80,000 skilled people in 20 countries, they produce 28 million tonnes of steel a year. Tata Steel is part of the Tata Group, one of the world's most respected companies, which employs 350,000 people in more than 80 countries in seven global business sectors.

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**FIGURE 7:** A choice of powder deposition nozzles enables a full range of components to be cladded with the greatest powder efficiency. The coaxial ring is used for fine detailed work; the four port (discontinuous coaxial) nozzle enables all positional cladding; and the off-axis nozzle is used where process robustness is required, i.e., for beam on times of several hours.