WHITE PAPER
COST-SAVING LASER CLADDED ALLOYS FOR WEAR CONTROL

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INTRODUCTION

Laser cladding of Nickel based cermets with inclusion of Chrome or Tungsten carbides is an obvious material choice when extreme wear resistance is required often in combination with harsh service conditions in terms of temperature exposure and corrosive environment. Also laser cladded Cobalt alloys are proven performers when it comes to combining wear- and corrosion resistance. However, Nickel and Cobalt alloys can be subject to increasing cost and due to further productivity enhancement, the material allocation can become the **main cost driver** for the cladding product. ***AS SUCH THE ADDRESSED QUESTION IS IF THERE ARE COST-SAVING ALTERNATIVES FOR INCONEL 625 TCC?***

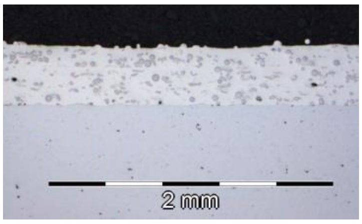
This paper describes the principles of wear resistance augmentation with laser cladding and next compares a default laser cladded **Inconel 625 TCC** with 2 types of alternatives.

- The first type of alternatives target **direct cost savings** and are illustrated by LCV's "**SS 55**" material which is a stainless steel with 55HRC hardness. It are more generic alloys which due to their laser cladded microstructure approximate wear resistance of higher alloyed materials.
- The second type of alternatives promote **total cost of ownership** and are illustrated by LCV's "**Impac-10X**" material which features improved abrasive and erosive wear resistance.

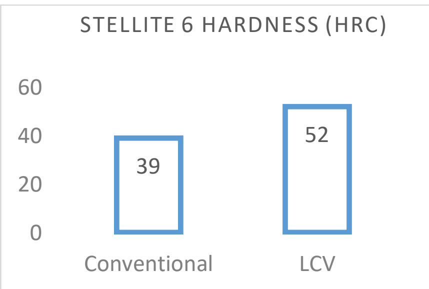
WEAR RESISTANCE FEATURES OF LASER CLADDED MATERIALS

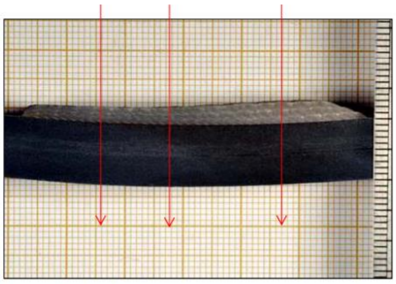
Laser cladding materials offer by their process-induced microstructure **beneficial features** which lead to augmented wear resistance.

First of all, Laser cladding is a welding process and as such a full **metallurgical bond** is established. To control the welding process due characterisation of the weld is prerequisite and the clad needs to be executed according a standardised welding procedure in order to avoid material defects such as substrate or overlay cracks and different types of detrimental porosity.

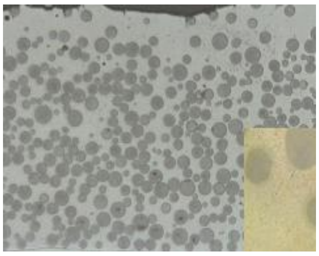
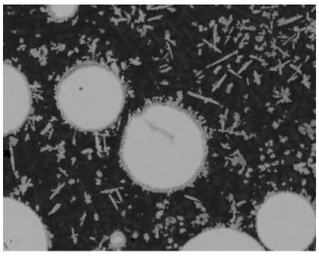


A second element is the minimal and topological heat input which leads to rapid solidification, which results is a **fine and uniform microstructure**. For certain materials, the microstructure induces extra hardness and wear resistance. For example, MIG applied Stelite 6 features a hardness of 39 HRC compared to a laser clad 52HRC CorroSlide hardness. The same effect can be realized for stainless steel 431L and certain super alloys like Hasteloy.

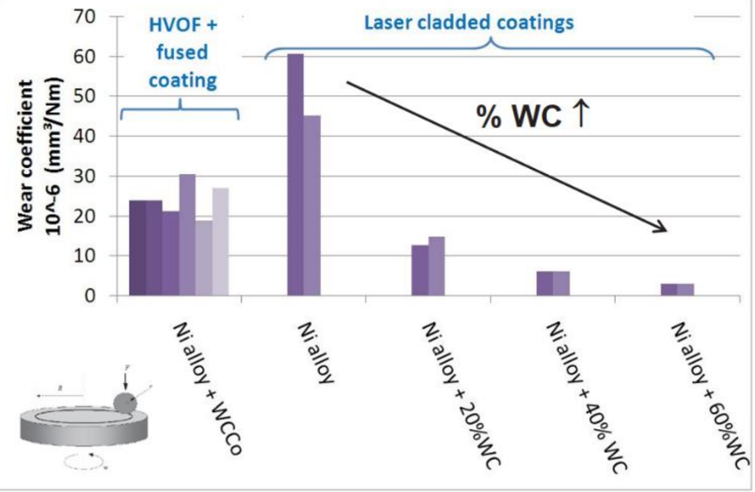




A third element is the **ideal metallurgic integration of the carbides** which avoids them to “break free”. LCV observes minor dispersion around the carbide edges. These structures function as an anchor with the matrix and discourages carbide wear-out and promotes wear resistance.

 CorroSlide TCC	 CorroSlide TCC

This results on average in **improved wear resistance**. Lifetime prediction is subject to service condition but on lab scale, laser cladded TCC coatings perform on average up to 4 times (4X) better than sprayed hard metallic overlays and conventionally welded hard-facing.



For weld-overlay and hard-facing LCV features 2 product types:

- The **CorroSlide** coatings for freeform objects with a thickness between 0.5mm and 2.5mm
- The **UltraClad** coatings for cylindrical cladding with a thickness between 150µ and 450µ

The **CorroSlide** products are used in the domain of conventional welding while the **UltraClad** products offer an alternative for thermo-spray and galvanic coatings such as Hard Chrome. Most coating products are available in multi-layer application.

	LCV-CorroSlide (mm)				LCV-UltraClad (µm)		
Layer Thickness	2,5	2	1,5	1	450	270	150

The benefit of the CorroSlide coatings is that they are thicker and this gives **extra toughness** to a coating. From a weld-technical point, 80% of the heat input goes into the substrate. For UltraClad coatings, 80% of the energy goes into melting the feed-stock.

Other benefits are;

• Minimal heat input • Minimal heat affected zone	• Minimal dilution & efficient material use • Fully dense material

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BASELINE – INCONEL 625 TCC

DESCRIPTION

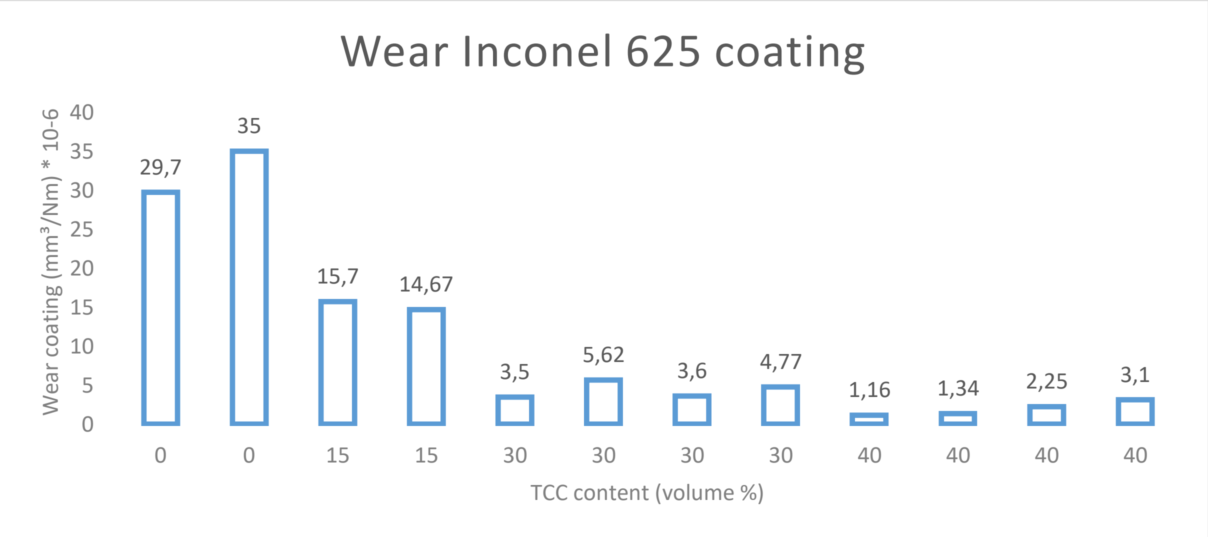
Inconel alloys are oxidation and corrosion resistant materials well suited for service in extreme environments subjected to pressure and **heat**. When heated, Inconel forms a thick, stable, passivating oxide layer protecting the surface from further attack. Inconel retains strength over a wide temperature range, attractive for high temperature applications where aluminium and steel would succumb to creep as a result of thermally induced defects. The embedded optimal carbide structure renders the LCV CorroSlide and UltraClad materials extremely wear resistant.

Field of application	Abrasive wear resistance in combination with high temperature and chemical corrosive service condition (at 800°C service condition)
Material Composition	NI, 0.05%C, 0.30%MN, 0.003%S, 0.25%SI, 20.00-23.00%CR, 4.00%FE, 9.00%MO, 3.50%CO+TA, 0.30%TI, 0.30%AL, <0.015%P

MATERIAL PROPERTIES

The hardness of the Inconel TCC material is defined as the average hardness of the soft matrix and hard carbide content. As such, the material blends the ductility and toughness of the Inconel matrix with the extreme hardness of the carbides. A typical bend is a 70/30 mix which results in 866V or approximately 64 HRC (30% Carbides (2700-3000HV) + 70% Inconel 625 (370HV) = 866HV).

As such, increasing TCC content promotes hardness and wear resistance.



For many applications, Inconel 625 TCC is a <u>proven performer</u> as it benefits from the Inconel 625 reputation and combines this with the ideal carbide integration which yields enhanced abrasion resistance. Caution applies for the abrasive media as very fine granulate (P50 and less) can erode the softer Inconel matrix.

Prior art with the LCV CorroSlide Inc 625 TCC product demonstrated that at elevated temperature of 800°C the Inconel 625 remains sufficiently strong. As such the matrix holds the carbide elements in place and as such the <u>wear resistance remains intact at high temperature</u>.

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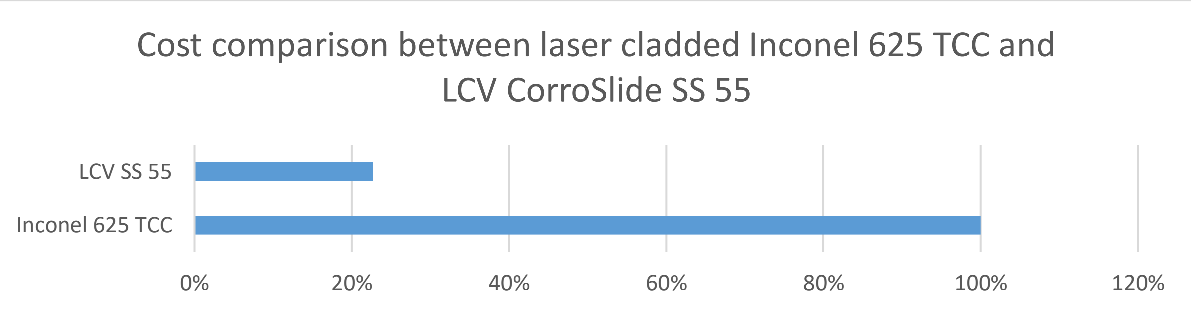
OPTION 1 – STAINLESS STEEL 55 *(DIRECT COST SAVING)*

LCV proposes the SS 55 material as a laser cladding blend of martensitic chromium-nickel stainless steel which, due to its specific micro-structure, features an **increased hardness** of 55 HRC for UltraClad coating (200 µm-450 µm) or **59 HRC for the CorroSlide coating** with thickness from 1mm to 2.5 mm.

Beneficial is that it features a **700 °C** working temperature and "last but not least" is the **cheaper** raw material.

Compared to Inconel 625 TCC, the material underperforms in terms of hardness, corrosion resistance and service temperature, but from a clad-technical viewpoint it can be easily applied both as UltraClad and CorroSlide coating and comes with a **clear cost reduction of 77%** on consolidated material- and machine cost.

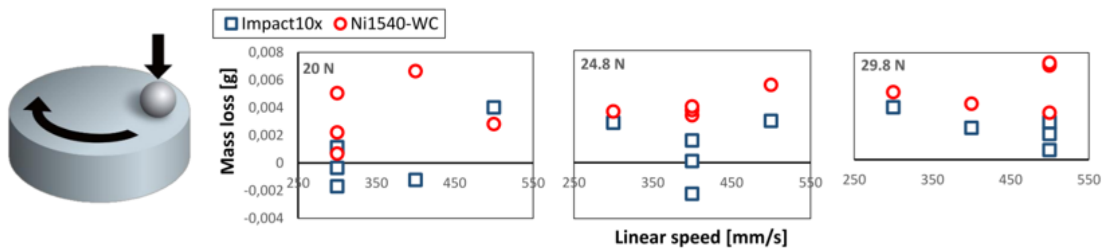


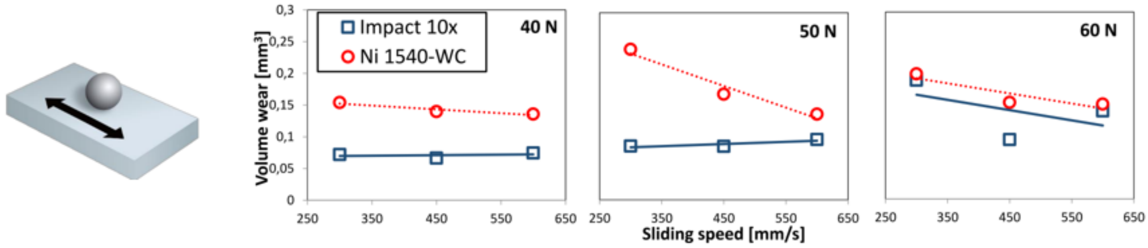
The SS 55 material is a significant cost saving alternative and can be applied at elevated temperature. Hardness is with 59HRC not in the same 60+HRC category as an Inconel 625 TCC but it concerns a mono-alloy which offers good wear resistance to both coarse and fine gritted abrasives. Corrosion resistance is based on the martensitic high chromium base material and can suit a wide range of applications.

OPTION 2 – IMPAC-10X *(TOTAL COST OF OWNERSHIP)*

The Impac-10x is a high impact- and wear-resistant material with a **fine "simulated" carbide interstition**.

This material has been tested and compared with Ni-based TCC for wear by the Labo Soete at Ghent University (BE). Impac-10x clearly demonstrates **extra abrasion resistance** compared to Ni TCC.

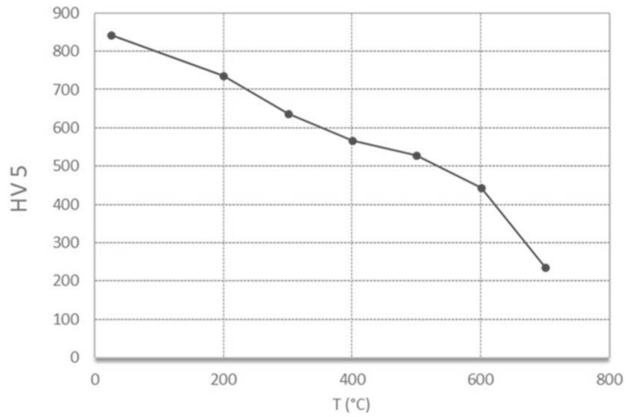




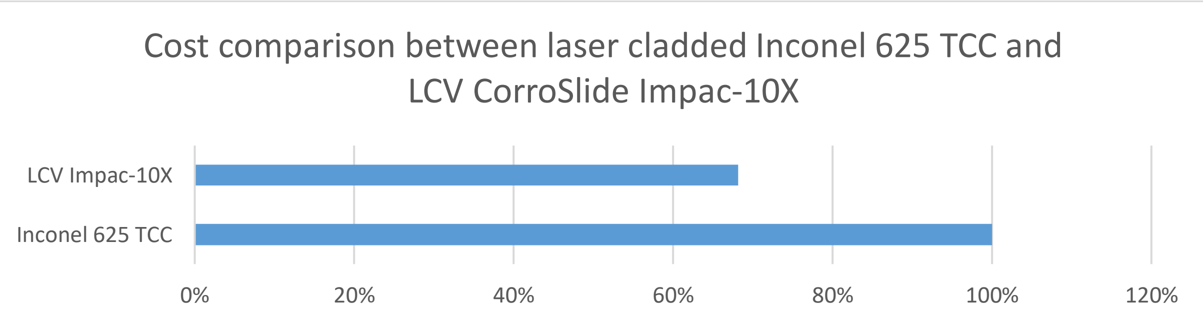
The hardness is circa **60-65 HRC** and it is also a tough material with **excellent impact resistance** *(hence the name Impac-10x because the impact strength is 10 times better compared to an average cermet blend).*

This is a LCV CorroSlide material that can be applied in low thicknesses from 0.9 mm to about 1.5 mm with a supplied machine stock of 0.5mm to approximately 0.7mm.

On the downside, the temperature resistance is less optimal as het Impac-10X "loses" about 25% of its hardness at 500°C working temperature.



From a weld-technical point, the Impac-10X material requires careful clad execution and in terms of feed-stock it relies on a specific alloy with higher cost compared to SS 55. This makes that compared to the baseline Inconel 625 TCC material, a **32% cost saving** can be realized.



The IMPAC-10X material is an interesting material when both wear resistance and toughness is required. The material is less suited for high-temp applications or corrosive service conditions. It is a speciality material which represents still a cost saving compared to the Inconel 625 TCC cladding and for selected types of applications it can yield significant TCO savings.

CONCLUSION

Laser cladding of Inconel 625 TCC is a gold-standard as it combines excellent wear resistance in both corrosive and high-temperature service conditions. This paper demonstrates that novel laser cladding blends can yield both direct cost saving *(in the case of SS 55)* and combine these with improved wear resistance and TCO *(in the case of Impac-10X).*

Key in selecting a laser cladding material is the fit-for-purpose consideration and next the state-of-the-art execution of the clad process based on diligent project engineering.

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