WHITEPAPER

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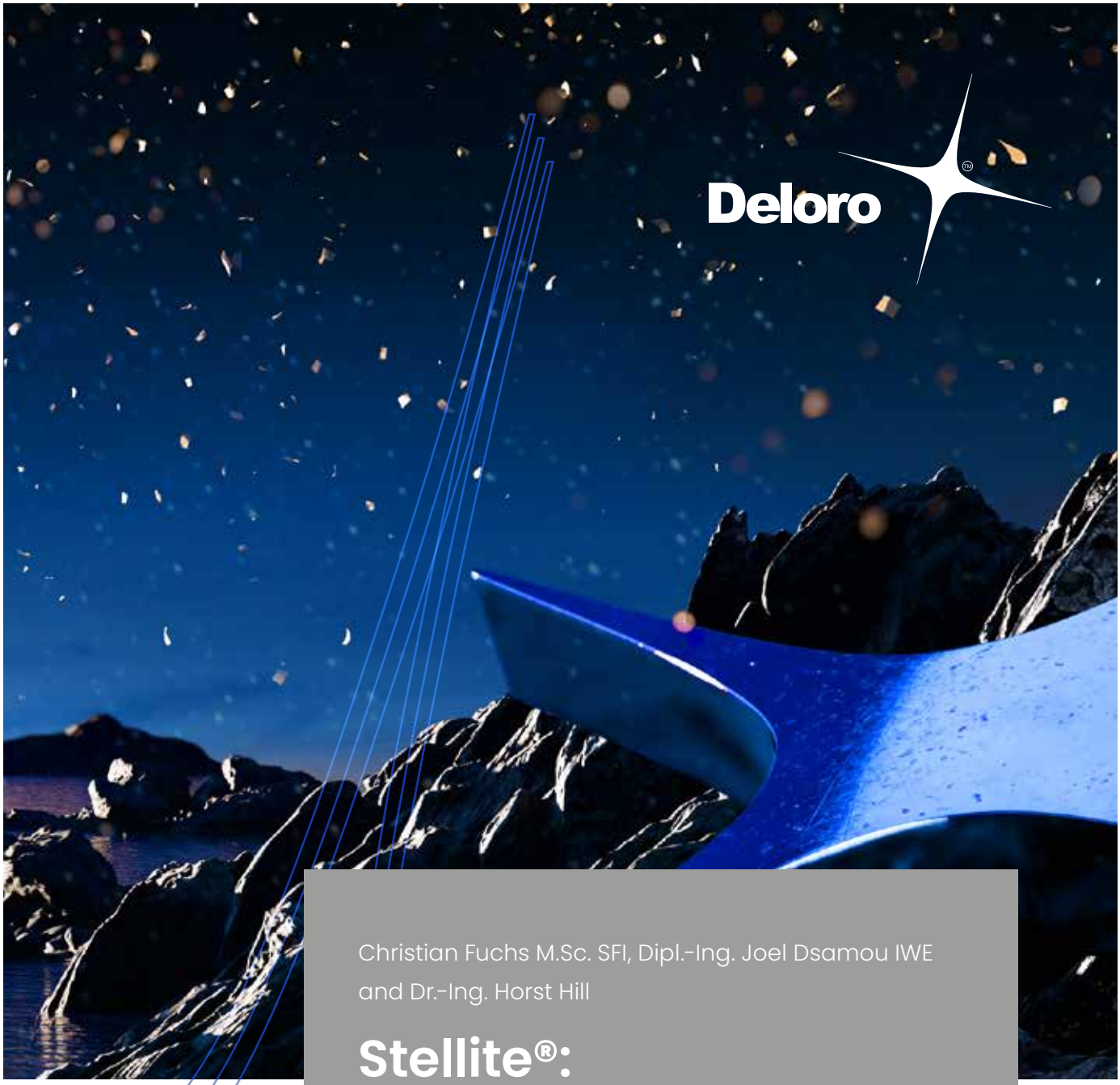

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Stellite®: Challenges in the welding process

What you need to know about the all-rounder among our alloys

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Table of Contents

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Editorial

Dear Readers.

In today's industrial landscape, precision and durability are paramount. Welding deposition has become increasingly vital — not only for reinforcing or repairing components but also for tailoring material properties to meet specific demands. This technique is especially crucial when working with highly specialized materials designed to endure extreme conditions.

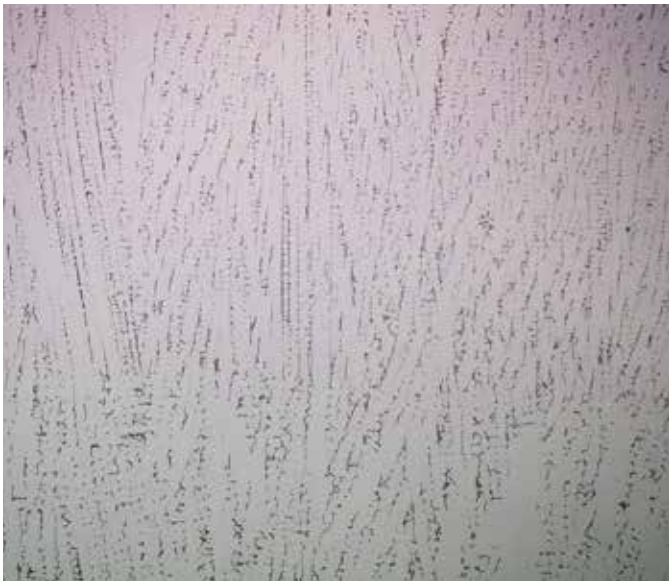
At Deloro Wear Solutions, we trust Stellite® as our go-to material for challenging welding applications. Renowned for its outstanding resistance to corrosion, wear, oxidation, and extreme temperatures, Stellite® demands equally advanced welding techniques. Additive manufacturing with Stellite® alloys, in particular, requires deep metallurgical expertise and robust technical know-how.

This whitepaper offers a comprehensive overview of the various Stellite® alloys. It outlines proven welding techniques for processing these materials, discusses the challenges and key considerations in welding deposition, and explores recent advances in additive manufacturing using Stellite® alloys.

We hope you enjoy the read!

Jasmin Lang
Director Welding Equipment, Materials and Marketing

Cross-section of Stellite® 6



Cross-section of Stellite® 21

Stellite® and its Characteristics

Stellite® alloys are cobalt-based materials featuring a cobalt-chromium matrix enriched with complex mixed carbides. These alloys are widely used across industries such as pumps and valves, paper and plastics, steam turbines, and nuclear applications. At Deloro, we classify these alloys into two primary systems:

1. **Cobalt-Chromium-Tungsten-Carbon System**
   These include alloys such as Stellite® 1, 6 and 12. A characteristic feature of this system is the formation of carbides, i.e. metal-carbon compounds such as M7C3, which have high hardness and temperature resistance. The basic rule is: the higher the carbon content, the more carbides are formed and the harder the alloy becomes. However, this also leads to increased susceptibility to cracking, which makes welding more difficult.

2. **Cobalt-Chromium-Molybdenum/Tungsten System**
   These include our Stellite® 21 and 25 alloys. These consist mainly of solid-solution strengthened phases with significantly fewer carbides due to their low carbon content compared to the cobalt-chromium-tungsten system. However, they offer exceptional corrosion, oxidation and high-temperature resistance. They are therefore particularly suitable for applications in aerospace (e.g. gas turbines), valve technology and the medical sector.
   Due to the low carbon content, toughness is improved and welding is easier.

Both alloying systems contain minor alloying elements such as nickel (Ni), iron (Fe), manganese (Mn) and silicon (Si), which further influence the properties of the alloys.

Iron and nickel stabilize the face-centered cubic (fcc) structure. This is beneficial for ductility, but detrimental to strength and corrosion resistance. Both these alloying elements, but particularly iron, are cheaper than cobalt.

Mn and Si are particularly important for manufacturability (= fluidity of the melt and deoxidation). In alloys with intermetallic phases (such as Tribaloys), Si participates in the formation of the intermetallic phases and is therefore an important alloying element.

Despite their wear resistance, Stellite® alloys offer good weldability when the parameters are adjusted to the specific requirements of the components being hardfaced. Deloro offers Stellite® alloys in the form of powder, rod, wire and electrodes, which are suitable for a wide range of welding techniques. Another advantage is the comparatively low preheat required when depositing Stellite®, especially when compared to nickel-chromium-boron-silicon alloys (e.g. Deloro® alloys), which have a similar hardness to Stellite®. This low heat input minimises the risk of distortion and cracking and facilitates use in thermally sensitive applications.

Weld Deposition Processes suitable for Stellite® Alloys

The appropriate welding process for handling Stellite® alloys depends largely on the required properties and area of application of the component being hardfaced. Plasma-transferred arc (PTA) welding and laser cladding have proven particularly suitable in practice, as they offer high reproducibility and process stability.

Compared to conventional welding processes, the PTA process has the advantage of a high degree of automatability, which guarantees consistent welding quality. Laser cladding can similarly be automated and also enables a microstructure with a significantly finer grain structure due to the faster cooling rate, which leads to a higher hardness with identical chemical composition.

Deloro welding system "Premium Line" in use.

However, with both processes, one must carefully consider the choice of the hardfacing alloy in terms of layer thickness and susceptibility to cracking. Low dilution increases the hardness of the deposit, which improves wear resistance but also impairs weldability due to the higher cracking susceptibility.

Dilution with the base material, with the associated increased iron content, can have the following effects on Stellite® alloys:

- **Corrosion resistance:** As the chromium content of the alloy decreases to 20-25%, the resistance of Stellite® alloys in extremely corrosive environments is reduced. Nevertheless, this corrosion resistance remains higher than that of many stainless steels.
- **Alloy hardness:** Dilution reduces the hardness of the overlay alloy.
- **Wear resistance:** A reduced carbon content reduces the wear resistance.

Taking into account good adhesion to the base material, the aim should therefore be to achieve the lowest possible dilution. In the PTA process in particular, it is advisable to weld two layers: in the first layer, dilution will be high, so this layer should be applied as thinly as possible. The second layer is welded onto this base, allowing the Stellite® properties to fully develop. Careful heat management is required for optimum results, i.e. a certain minimum interlayer temperature must be maintained to prevent cracking in the Stellite® alloy and the base material.

Stellite® in Additive Manufacturing

Processing Stellite® poses a particular challenge in additive manufacturing. In laser powder bed fusion (LPBF) in particular, energy is applied extremely selectively, enabling the precise production of complex and delicate structures. The relatively rapid cooling rate leads to a finer microstructure and improves mechanical properties such as hardness, tensile strength and wear resistance. However, this also increases cracking susceptibility during printing, which makes the printed part prone to defects.

The 3D printing of Stellite® alloys is therefore particularly challenging and has not been widely adopted to this very date. Due to its low carbide content, Stellite® 21 is the most ductile alloy in the Stellite® portfolio, making it the first choice for additive manufacturing.

Continuous development is also taking place in this area. There are currently three options and processes available for overcoming the challenges of additive manufacturing with Stellite®. We have already tested all of these solutions.

Option 1: Preheating the powder, the build chamber and/or the build platform

The use of specially configured additive manufacturing machines that heat the powder to be printed and the build platform itself can reduce the cooling rate and thus minimise the risk of cracks in the workpiece. This process has been trialed at various research institutes. However, it is both time-consuming and costly in terms of equipment.

Option 2: Binder jetting

In binder jetting, i.e. free jet binder application, 3D printing takes place without direct energy impact during the process. The powder bed material is not melted directly by a laser or other energy sources; instead, it is selectively bonded and the resultant component is then separated from the powder bed and sintered in a furnace. This method prevents thermally induced cracking during the 3D printing process. However, it requires the use of a special powder with a precisely defined particle size distribution. In addition, sintering leads to shrinkage due to binder loss, which makes it difficult to produce parts with tight tolerances. Residual porosity in the workpiece cannot be completely ruled out either.

Option 3: Material development

The hope lies in material development. Here, the chemical composition of the powder is specifically modified to reduce crack sensitivity carbon content, which can initially result in a lower hardness. However, the faster cooling rate results in a finer structure, which in turn improves the properties of the component. The end result is a component with optimal mechanical properties that is much easier to print. Another advantage of this method is that material development can be carried out using common printing systems that are already established on the market.

Our Stellite® alloys are suitable for all three options described above, offering flexible options for various application requirements in additive manufacturing.

Stellite®: A reliable and durable All-Rounder

There is no one correct method for welding Stellite®. The choice of welding method depends on the properties that the material should have at the end of production. In summary, one can say that Stellite® alloys are not only extremely durable, but also versatile. Thanks to their exceptional wear and corrosion resistance, they are ideal for use in industrial applications. Their efficiency and robustness make them durable and perfect for demanding environments.v

If you have any questions, the experts at Deloro are here to help:

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