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Laser Detonation Enhanced Supersonic Metallic Coatings

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1. Introduction

Metallic coatings provide a number of advantages such as protection to corrosion or abrasion in order to increase the lifetime of a component. The global industry for paint and coatings is expected to grow in coming years and reach $141 billion by 2015.

One such coating technology is Supersonic Laser Deposition (SLD). This 3 year PhD project aims to improve this process through the addition of a high energy pulsed laser to control the coatings stress state, increasing its resistance to cracking and fatigue.

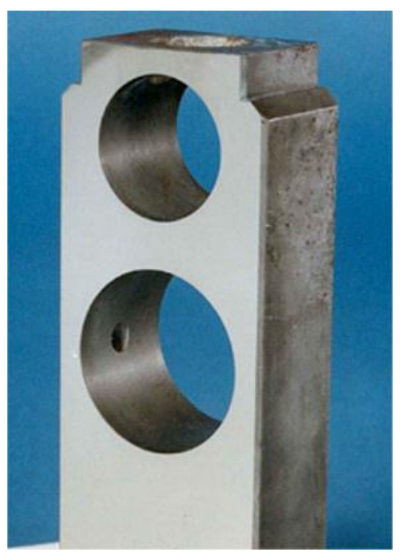

Figure 1: A tungsten carbide coated gate valve used on oil rigs to resist abrasive wear. [1]

2. Supersonic Laser Deposition (SLD)

The SLD process enables the solid state (non-melting) deposition of powdered coatings onto metallic and non-metallic substrates.

When compared to melt based processes SLD has the advantage of retaining the enhanced nano-structured properties of the coating material, such as low friction and hard wearing [2].

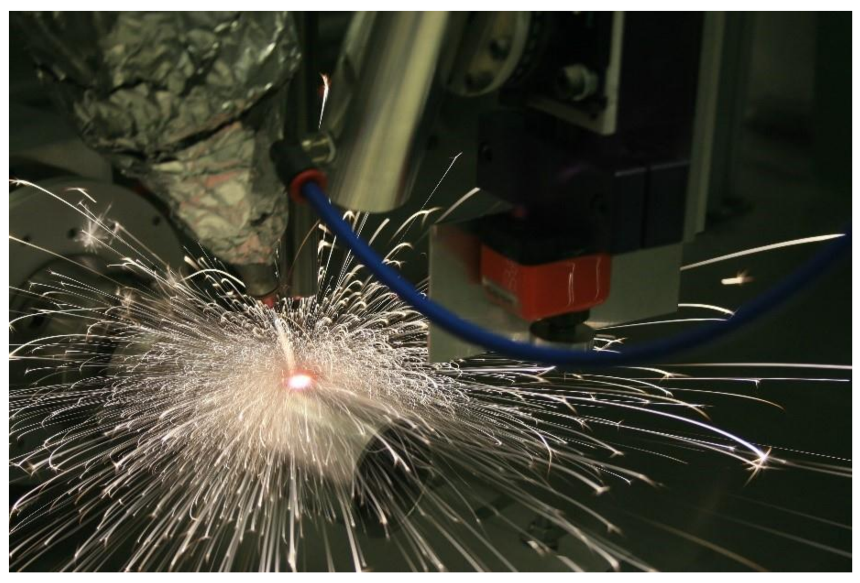

Figure 2: The existing SLD process in action.

3. Process Limitations

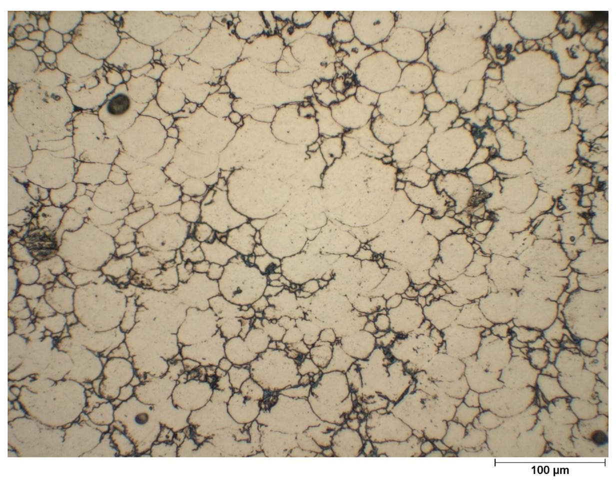

Figure 3: Cross section of a Titanium track deposited using the SLD process.

SLD accelerates micron size powdered particles up to speeds approaching 700 ms^{-1} through the use of supersonic gas streams. The particles impact on a substrate, which has been "softened" with a multi kilowatt laser, and plastically deform the lower layer to build up a dense coating.

On some materials the current process leaves gaps between individual particles, Figure 3, which can lead to problems such as cracking and delamination. The coating needs better consolidation and an increase in bond strength. This would increase the performance of the coatings in applications of high density coatings for hard facing or the repair of engineering components.

4. Proposed Mechanism

Traditional laser shock processing relies on generating a compressive shock wave at the surface with the use of laser induced ablation, often with an overlay layer to confine the energy. Such processes typically require lasers pulses with power densities of several $\mathrm{GW/cm^2}$.

The proposed model here uses a high intensity pulsed laser beam to rapidly heat the top surface of the metal coating, inducing an acoustic compression stress-wave from the rapid expansion of the material in a small volume, Figure 4. Power densities required are less than $1\ \mathrm{GW/cm^2}$[3].

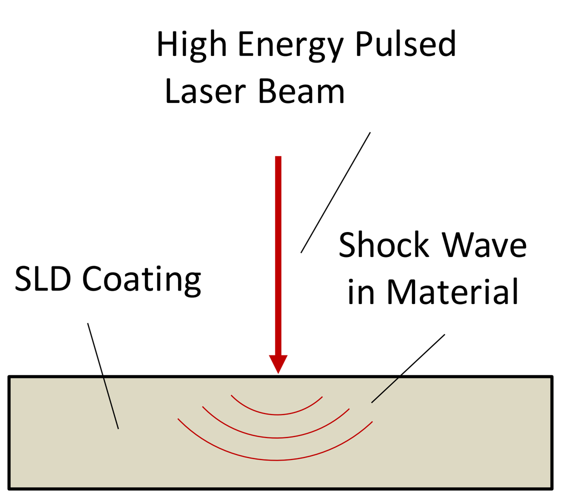

Figure 4: Diagram of incident laser beam on metallic coating.

The compression stress-wave passes through the metallic SLD coating and can have sufficient energy to alter the position of the particles in the coating to a depth of over 1mm, leading to increased consolidation and residual stresses of the order of several hundred MPa.

The current work is looking at validating this shock mechanism for SLD samples and determining how the laser beam energy, power densities and pulse period affect the consolidation and residual stresses, Figure 5.

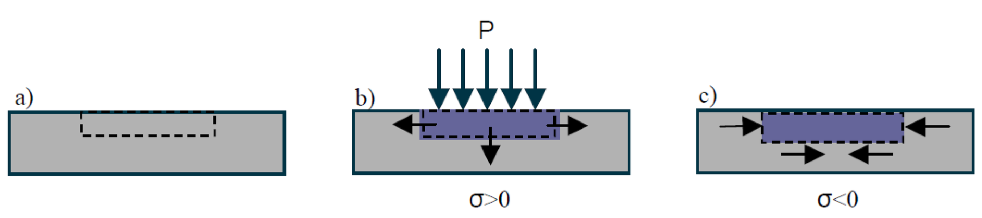

Figure 5: Illustration of principle for generating residual stress [4].

5. Future Work

Once the laser parameters to induce laser induced detonation have been determined, an investigation will be undertaken to further investigate the mechanisms with a view to integrating them into a system capable of being commercialised. In addition to this a theoretical model will be developed to better understand the stress states within the SLD metallic coatings.

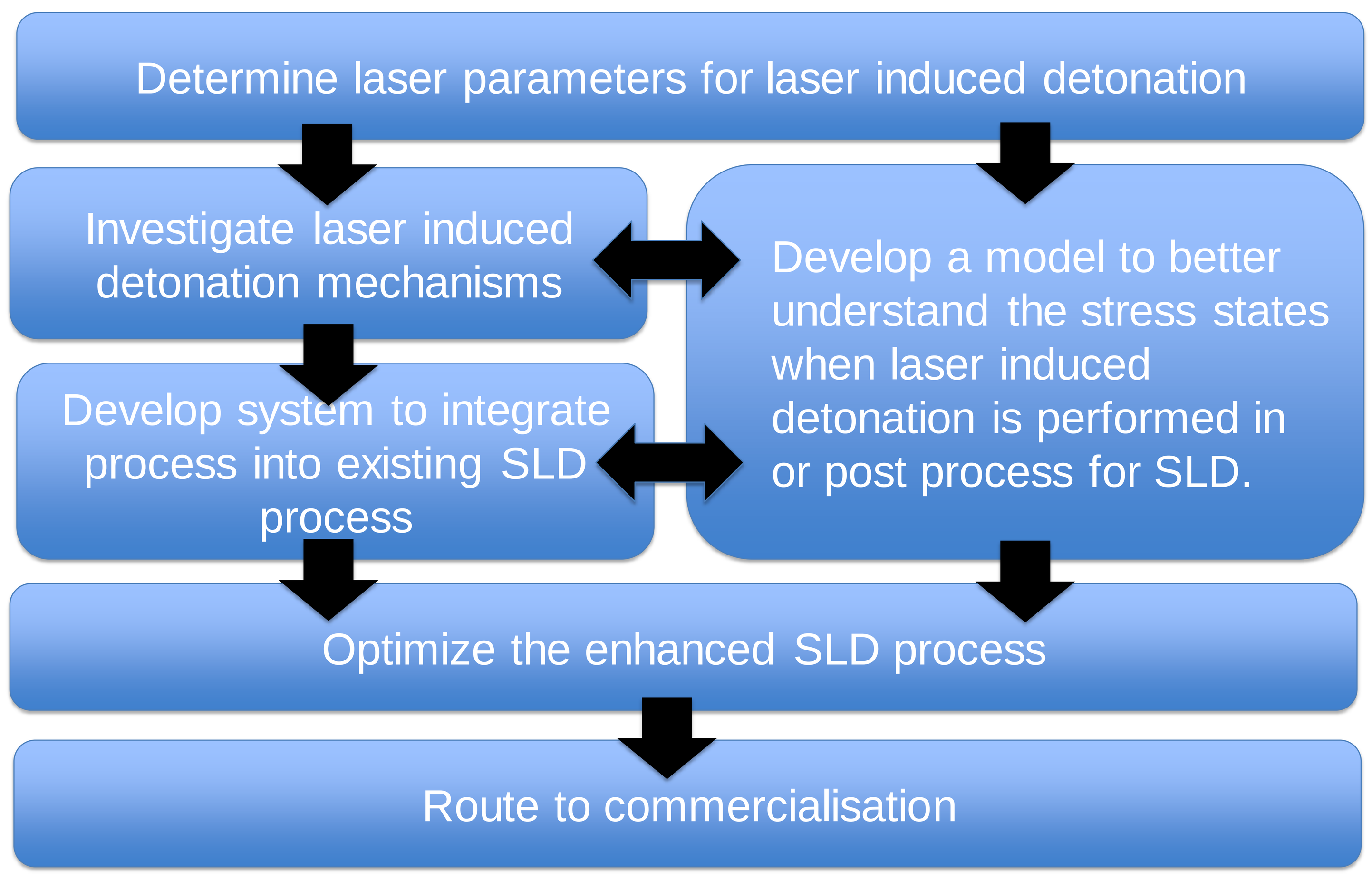

Figure 6: Diagram showing the proposed future stages of the project.

References

[1] www.offshore-technology.com/contractors/corrosion/bodycote-coatings/
[2] M. Bray, A. Cockburn, and W. O'Neill, 'The Laser-assisted Cold Spray process and deposit characterisation', *Surf. Coat. Technol.*, vol. 203, no. 19, pp. 2851–2857, Jun. 2009.
[3] J. Rabinovich, 'Process for energy beam solid-state metallurgical bonding of wires having two or more flat surfaces', US 2010/01553742010.
[4] S. H. Niehoff and F. Vollertsen, 'Laser induced shock waves in deformation processing', *Metalurgija*, vol. 11, no. 3, pp. 183–194, 2005.

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