Fundamental Studies of Cold Spray Titanium

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CSIRO has invested generously in titanium research through CSIRO Light Metals Flagship.

The Cold Spray group at LMF recognised the potential of cold spray technology for direct manufacturing and successfully adapted it for the direct manufacture of large titanium components. For example, CSIRO has developed an innovative technology for direct manufacturing of continuous seamless titanium pipe using Cold Spray. This technology is in the process of commercialization. CSIRO has taken further step and established Victorian Direct Manufacturing Centre where Cold Spray Technology has a major role.

In Cold Spray, micro-particles are accelerated in the solid state by an inert, supersonic gas flow and impact against a substrate surface, resulting in the build up of a deposit. Since in-flight temperatures do not approach melting point, many of the problems associated with high temperature thermal spray techniques such as melting, vaporisation, oxidation and thermal stresses, are avoided. In this study, the processes of bonding and microstructural evolution in cold sprayed titanium are investigated. Two different commerical titanium powders were cold sprayed, and shown to have undergone plastic deformation at very high strain rates, resulting in extensive refinement in microstructure. Large nanostructured areas were produced with high dislocation densities and subgrain sizes less than 100 nm. Dense dislocation tangles, twins and elongated subgrains were observed in other places. Adhesion of titanium particles occured due the formation of adiabatic shear bands at the particle interfaces. The disruption of oxide films was observed there.

To simulate different aspects of the Cold Spray process, a computational technique known as Smoothed Particle Hydrodynamics (SPH) is being developed and applied. It is a technique designed for modelling continua including gasses as well as solids. As such, it is a versatile numerical method in which, multiple types of physics can be incorporated and solved. Unlike most numerical techniques for computationally modelling continua, SPH does not utilize a fixed nodal grid on which discrete forms of the equations of motion are solved. Instead, the discretised equations are solved on a collection of discrete "nodes". Each node carries mass, momentum, stress and energy and moves with the local fluid or solid velocity. Appropriate equation of state for the fluids and solids are included to close the equation set. Two different applications of the CSIRO SPH technique are under development in the Cold Spray group. The first is modelling the flow of inert gas through the Cold Spray nozzle and the subsequent motion of metal particles that are injected into the nozzle plenum. The second is the simulation of the impact of individual metal particles onto a substrate. The automatic coupling of the second application with the first via a multi-scale modelling approach is the long-term aim of this work.