Characterisation of Stainless Steel Cold Spray Coatings on AZ91 Mg Substrates

ARC Centre of Excellence Design in Light Metals

M. Schwartz, K. Spencer and M.-X. Zhang

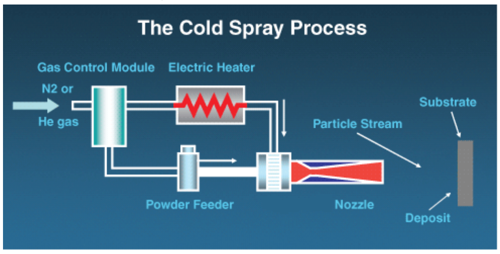
The University of Queensland Australia

Introduction

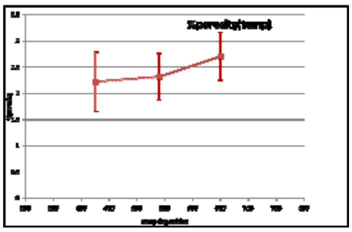
Magnesium has properties which are attractive for automotive and aerospace applications: it has a low density, for example it is 1/3 lighter than aluminium. The use of Mg or one of its alloys like AZ91 is limited by its poor corrosion and wear resistance. One solution is to coat the surface with a more corrosion resistant material such as stainless steel. The low temperature of the cold spray process makes it suitable for thermally-sensitive substrates like Mg alloys.

Experimental Methods

KM, a variation of the cold spray process, is a material deposition process whereby particles between 1 and 40 microns in diameter are impacted at high velocity onto a substrate. The particles are placed in a gas stream of nitrogen, helium or air. The stream is then heated and accelerated through a converging nozzle. The particle stream is directed towards a substrate, where the particles are consolidated in the solid state. KM is an entirely solid-state process, although a small quantity of heat is applied to the powder, melting never occurs.

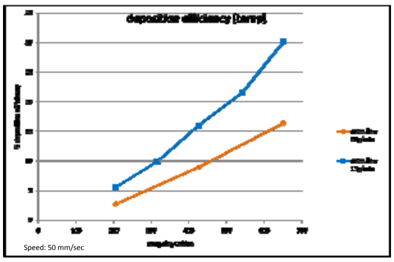


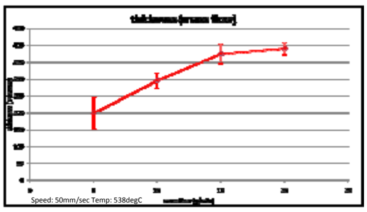
Properties of Sprayed Coatings

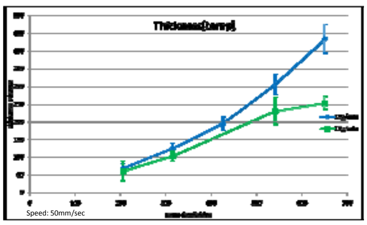


The data to the left shows that varying the spray temperature from 425°C to 650°C has no effect on coating porosity. This enables lower spray temperatures to be used for more thermally sensitive substrates. In addition, changing the mass flow rate of the powder did not affect coating porosity.

The deposition efficiency is the proportion of powder deposited on the sample; the rest of the powder rebounds from the substrate. Increasing the mass flow of powder decreases the deposition efficiency. However, the deposition efficiency increases when the gas temperature increases, which increases the speed of the gas through the nozzle.





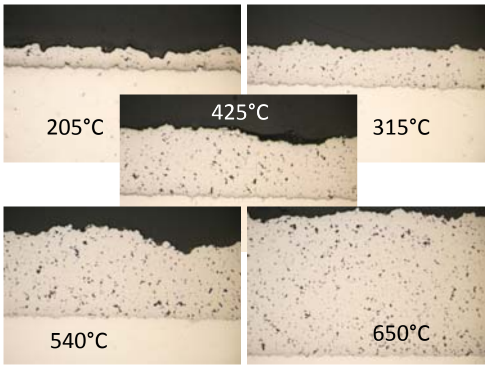


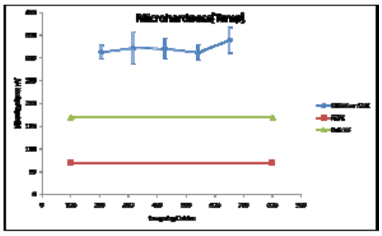
Increasing the powder flow rate up to 20g/min increases the coating thickness. Beyond this point, the thickness does not increase any further – the powder is no longer dilute in the gas stream and cannot accelerate to the critical velocity for adhesion to the substrate.

Increasing the gas temperature up to the limit of the cold spray system (650°C) increases the coating thickness; this is consistent with the increase in deposition efficiency.

Microstructure and Corrosion Behaviour

The micrographs to the right are sections of the coating/substrate interface. We can see the increase of thickness with increasing gas temperature during spraying. However the porosity is unchanged. In all cases there is good bonding between the substrate and coating.



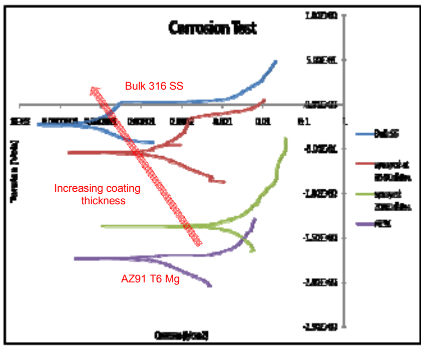


We can observe that the gas temperature does not change the microhardness in the coating, but we see that there is extensive plastic deformation of the coating.

Increasing the coating thickness leads to a transition in anodic polarisation behaviour, as shown on the right.

In the case of thin coatings the polarisation behaviour of the stainless steel coating is similar to the AZ91 substrate.

With thicker coatings, the anodic polarisation behaviour approaches that of bulk 316 stainless steel.

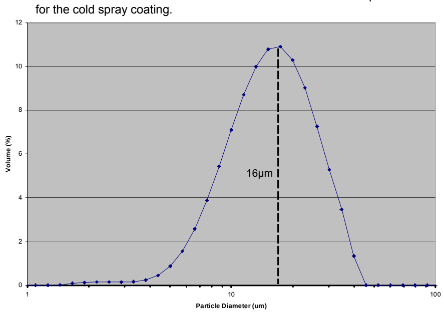


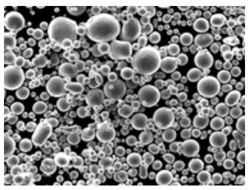
Summary

For improving the wear resistance and, more importantly, the corrosion resistance it is not enough to cold spray deposit a coating of stainless steel. We can readily optimise the deposition efficiency and the thickness, but not the porosity. Eliminating the porosity is needed to improve corrosion resistance, and will be the focus of future work.

Powder

Here we can see the size distribution from the stainless steel powder uses for the cold spray coating.





Stainless steel powder

Future Work

- •Add small-size stainless steel powder
- • Mixed Zn/SS coatings, heat treated to form dense intermetallic composite coatings
- •Add small-size Ni powder to close the porosity
- •Add Al_2O_3 powder to the SS