Cold Spray consolidation of Nanostructured AA5083 Aluminum Powder

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Introduction

Cold spray is a materials deposition process whereby combinations of metallic and non-metallic particles are consolidated to form a coating or freestanding structure by means of ballistic impingement upon a suitable substrate [i, ii, iii]. The high velocity gas stream is generated via the expansion of a pressurized, preheated, gas through a converging-diverging de Laval rocket nozzle. The particles, initially carried by a separate gas stream, are injected into the nozzle and are subsequently accelerated by the main nozzle gas flow and are impacted onto a substrate upon impact, the solid particles deform and create a bond with the substrate [iv, v]. The term "cold spray" has been used to describe this process due to the relatively low temperatures (-100 to +100° C) of the expanded gas stream that exits the nozzle.

The low temperatures associated with the cold spray process are desirable when considering the use of nanostructured powders as feedstock because the risk of grain growth and phase transformation is minimized or nonexistent. This work describes how cold spray was used to consolidate a nanostructured Al powder coating for possible wear applications.

Experimental

Nanocrystalline AA5083 (N-werks) was used as feedstock powder. Fig. 1.0 shows that the powder contains many large agglomerates which was supported by determining the particle size distribution (PSD).

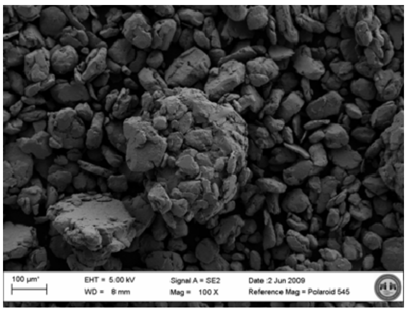

Fig. 1.0: Original n-WERKZ AA5083 feed stock used during the cold spray process. Note large agglomerates.

PSD measurements were obtained using a Horiba LA-910 Laser Scattering Particle Size Distribution Analyzer and are shown in Fig. 2.0.

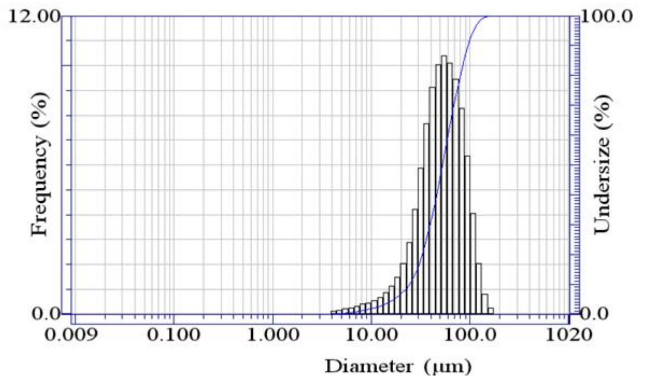

Fig. 1:Particle size distribution of AA5083 powder. The mean particle size was 56.7 µm

A K-tech cold spray system (Fig. 3.0) was used to deposit the AA5083 powder onto 6061 substrates. The deposits were then polished and mounted for metallographic analysis. To verify the preservation of the nano crystalline structure, TEM analysis was performed to measure the grain size of the coating.

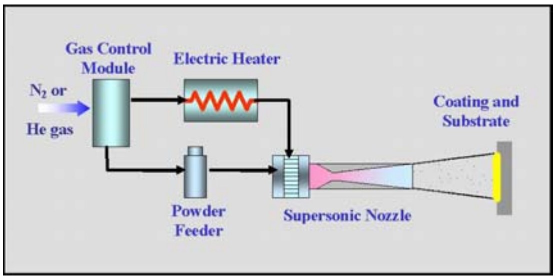

Fig. 3.0: Cold spray system schematic

Results and discussion

The predictive models developed by ARL can be used to determine the impact velocity of accelerating particles as well as the 'critical' impact velocity. The critical impact velocity can be defined, as that which results in adequate consolidation of the particles. Fig. 4.0 indicates, the critical impact velocity is approximately 650 m/s. Incorporating the cold spray process parameters used in this study with the accelerating gas set at a temperature of 400 °C and a main gas pressure of 400 psi, a 20 μm particle would achieve an impact velocity of 1438 m/s. However, the impact velocity of some of the larger agglomerates (> 120 μm) cannot be achieved using the process parameters described. This would explain the random voids observed within the structure of the cold spray deposit.

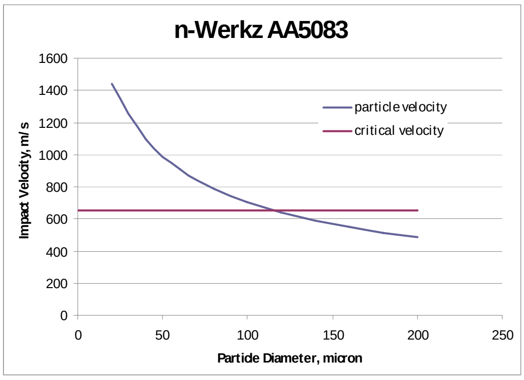

Fig. 4.0. Critical impact velocity calculated with the accelerating gas set at a temperature of 400 °C and with a main gas pressure of 400 psi.

The resulting AA5083 coating is seen in Fig. 5.0. There were random voids observed within the structure that were later attributed to large agglomerates found in the original feed stock powder. These agglomerates were in excess of 100 μm and as such would not completely deform during impact, leaving behind these occasional defects.

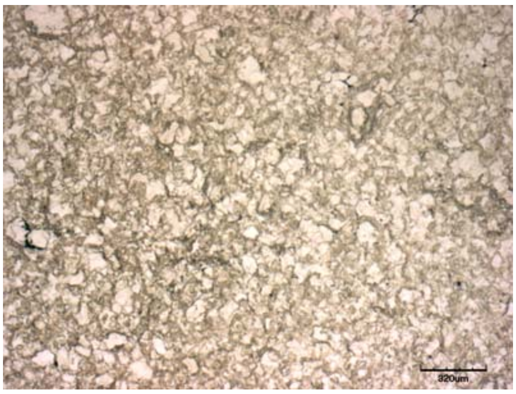

Fig. 5.0 Cold spray deposit of n-WERKZ AA5083. Confocal microscope.

A typical bright-field TEM micrograph from cold-sprayed AA5083. Deformation of fcc-Al from high particle velocity deposition resulted in elongated grains with aspect ratio ranging from 2~3 to 1. Mean grain size was approximated at 100 ± 35 nm. Between nano-grains, excellent chemical bonding without deleterious voids or inclusions was observed as demonstrated by the high resolution TEM micrograph in Fig. 6.0

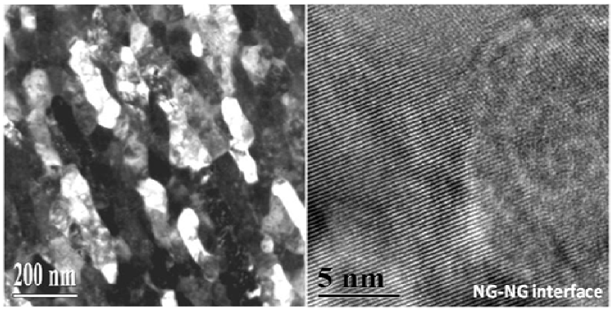

Fig. 6.0 TEM images of deposited AA5083 powder showing mean grain size of 100 ± 35 nm (left) and a grain boundary (right).

Inclusions and voids were occasionally observed at splat (e.g., prior particle) boundaries as presented in Fig. X.43. At the interface between AA5083 cold-sprayed coating and AA6061 substrate, excellent bonding was observed as presented in Fig. 7.0.

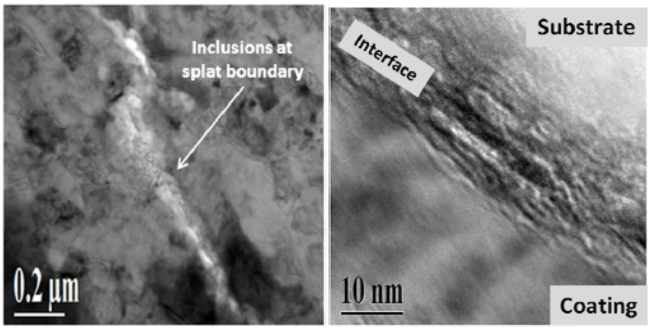

Fig. 7.0 TEM images of grain boundary inclusions (left) and the coating/substrate interface (right).

Conclusion

1. The cold spray process was able to deposit a nanocrystalline coating of AA5083. The mean grains size of this coating was determined to be 100 ± 35 nm
2. Oxide inclusions were found at grain boundaries
3. The substrate/coating interface is free from cracking and inclusions.

References

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