Axial Fed Micro Plasma Spraying in Additive Manufacturing

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Abstract: By transporting metal powder through the cathode of a common welding machine, we were able to produce cladding on the hunderth micrometer scale. The method may be used to realise near net shape additive manufacturing processes (3D printing) and show practical advantages

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1. Introduction

The main goal was a proof of principle. As such, focus was put on classifying the result and documenting the operating conditions. The experiment was to show powder fed axiallly through the cathode would enable precission cladding.

Additionally, it could be shown the process is quite insensitive to working parameters, such as arc power, powder flow rate or distance. (The limiting factor on distance turned out to be weather the welding machine could reliably hold an arc.)

Some perliminary observations were taken using a camera and image analysis. The arc was observed to have a much larger base point than the width of the applied cladding. It could be shown that powder was partially vaporised and ionised.

Powder-oxidsation was observed. Most likely, applying a pure argon atmosphere would enable better results.

2. Experimental Setup

A common handheld welding tool (Magic Wave 2500 by Fronius) was used to create and sustain the arc discharg. It supplied a shielding argon flow around the cathode. To transport powder through the cathode, a spare torch cap was cut open to reach the cathode with a brazen pipe. Through this pipe, a powder carrying argon flow could be supplied directly to the cathode.

Aerosolising the powder at the low flow rates expected had turned out to require much more expensive tools than anticipated. Therefore, a special powder aerosolation for small amounts had been built:

Powder was aerosolised by blowing argon through an injection needle into a glass cylinder and extracting the powder through another injection needle. A flow meter controlled the argon flowing into the glass cylinder. The argon was supplied from a separate argon bottle.

The cathode was a standard lanthanated welding cathode. A local machine shop used electrode erosion to drill a .3mm sized hole through the center axis.

To produce reliable cladding traces, the torch was fixated vertically. A round copper plate fixed to a motor so it could be rotated (off center) under the torch. The motor acted as ground for the welding machine.

The materials used were chosen for highest chances of success. Tin was used as powder, since it has a low melting point. In case a high powder velocity would be required, tin would not need to spend as much time in the arc to melt. Furthermore, tin doesn’t pose any additional health or explosion risks. This decision payed off when a faulty setup aerosolised the powder can contents into the workshop air. Copper was chosen as base material, since it mixes well with tin, but doesn’t melt as easily, enabling tests with higher arc currents.

A small chamber with an acryllic window was built for the arc discharge, since it was initially thought the powder flow might be high enough to place dust in the near vicinity. Though this turned out to be wrong for standard operation, powder did flow accidentially without the arc operating some times. Especially the camera required protection from fine dust particles.

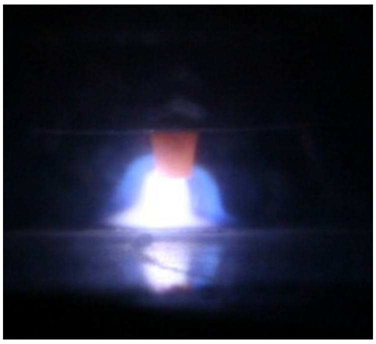
To observe the arc discharge, a digital camera (EOS650 by Canon) was placed in front of the acryllic window. A UV filter was used to protect the optics and electronics. Exposure time was set to the minimal possible value (1/4000 sec) to observe the arc.

3. Results

It could be confirmed that the described process can melt tin onto copper at flow rates of 30 to 120 sccm and arc currents of 10 to 40A, which results in an arc power of roughly 100 to 400W. The voltage was ramped up and down by the weld machine, but consistently jumped around 10(±1)V. The distance was varied between 1 and 10 mm and did not show any significant effct. The trace width stayed consistantly below .5mm.

Next to the trace, black soot was deposited which could be wiped away. It is not yet clear what this soot consits of, however, the working theory is that this is oxidised tin, which was vaporised and escaped the argon shield gas supplied by the welding machine. Less soot deposited at lower arc current would support this theory, since less power results in less tin getting vaporised.

Ionised tin recombining can be observed in pictures taken as blue glow not visible when no tin powder is supplied.



Measurements of the vapor cloud based on pictures will be reported.

Tin deposit thickness will be reported.

Interestingly, it had been remarked by companies contacted before the project started that powder back splash would occur due to the small distance between cathode and surface. This supposedly would jam the thin .3mm hole in the cathode. Though back splash did occur, it turned out to be no problem because the cathode could heat up and melt any jamming particles before the powder flow was initialised.

4. Application

This method was realised with low cost tools. The most expensive tool would have been the powder transport. Provided the deposits can be stacked reliably, this opens the possibility to low cost metal 3D printing. The arc plasma would effectively solve the problem of a high precision, high temperature heat source.

Additionally, since this mechanism seems to be immune to back splash, it may be used in precision plasma spraying.

5. Outlook

Further tests are planned with other materials, especially steal powder on a steal plate, as this would be a highly interesting material for additive manufacturing.

As mentioned, a test in pure argon atmosphere to avoid soot formation should be done.

Since the process works with a simple arc, it’s highly likely it would work with a plasma weld torch as well. However, at the required power and argon flow, a microplasma device would be required.

The restrictions of the powder source required the powder and argon flow to be adjusted simultaneously. A test with these two parameters individually would require investing into a powder source.