Powder spheroidisation for the Advanced Metal Initiative of South Africa using high temperature plasma technology

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Abstract:
Additive Manufacturing and plasma spraying requires metal or ceramic powders that are spherical with an improved flowability. Necsa is currently developing methods of spheroidising metals and ceramics for the South African market using a 15 kW plasma system from Tekna Plasma System Inc. Titanium is one of the metal powders that is being spheroidised and the results shows that the morphology of the powder was transformed from irregular to spherical, while the flowability and density were improved.

Keywords: Additive manufacturing, laser sintering, powder metallurgy, spheroidisation, titanium, radio-frequency plasma.

1. Introduction

Recently the manufacturing landscape changed significantly with emphasis on developing technologies to manufacture complex components cost and resource efficient on a small scale [1]. Additive manufacturing represent a technology where value chains are shorter, localized and more collaborative [2]. One such technology is 3D printing which require metal powders that are spherical with a higher flowability.

Plasma spraying is one of the thermal coating process which provides a thick coating over larger area at a higher depositing rate when compared to other coating process. This method prove to be efficient when coating materials are expensive such as precious metals and losses has to be minimized. Similar to spheroidisation, the plasma spraying method requires powder that is spherical with a higher flowability.

The Advance Metal Initiative programme in South Africa is a strategic materials science research and development programme focusing on mineral beneficiation. The programme was established by the Department of Science and Technology of South Africa, the South African Nuclear Energy Corporation (Necsa), the Council for Mineral Technology (Mintek) and the Council for Scientific and Industrial Research (CSIR). The AMI programme is made up of four networks namely; the Ferrous Metals Development Network, the Light Metals development Network, the Nuclear Materials Development Network and the Precious Metals Development Network.

Mintek is developing ferrous and precious metals based alloys for thermal and corrosive resistant layer deposition purposes, whilst the CSIR is looking mostly at the development of light alloys containing titanium and aluminium. The Ti and Al alloys are intended for the Additive Manufacturing (3D Printing) market in South Africa. Necsa is currently developing methods of spheroidising materials and alloys associated with the nuclear industry, such as zirconium alloys.

Necsa purchased a 15 kW plasma system from Tekna Plasma System Inc. using the National Equipment Programme, managed by the National Research Foundation of South Africa. The system was commissioned and the first sets of experiments were on spheroidising titanium metal powder and the results obtained are highlighted in this study.

2. Experimental

The spheroidisation of titanium metal powder was conducted in a 15 kW Tekna plasma system shown schematically in Figure 1. The experimental parameters are given in Table 1. In a typical experiment, the irregular shaped Ti metal powder was fed at the top of the plasma torch using argon gas as a carrier gas when the desired power level was reached. Upon entering the torch, the powder absorb energy from the surrounding gas until they reach their melting point. The spheroidisation occurs when the powder particle are in a molten state. Most of the spheroidised powder accumulated in the catch pot, while a mixture of fine and spherical particles accumulated on the chamber wall. The remainder of the fine particles (< 5 µm) were recovered in the collection pot of the cyclone and the filter.

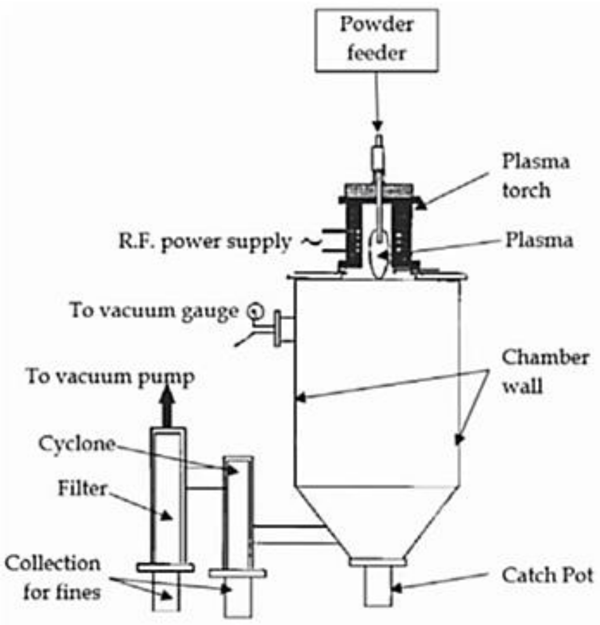

Figure 1. Schematic of the Tekna 15 kW experimental set-up

Table 1. Experimental parameters

Parameter	Value
Power, kW	9 - 13
System pressure, $kPa_{(absolute)}$	85
Plasma central gas (Ar), slpm	10
Plasma sheath gas (Ar + H_2), slpm	42-44
Powder carrier gas (Ar), slpm	2
Particle size, µm	150-180
Mass of powder treated, g	5
Feeding rate, kg/h	0.22

The morphology of the powders were observed by scanning electron microscope. The density of the powder was determined by a Gas Displacement Pycnometer. A large batch was treated in order to compare the flowability of the powders, the method requires *ca.* 50 g of powder to obtain accurate results.

3. Results

The SEM micrograph of the starting powder and the spheroidised powder are shown in Figures 2 and 3. From these figures, it is clearly evident that the treated powder was transform to a spherical morphology.

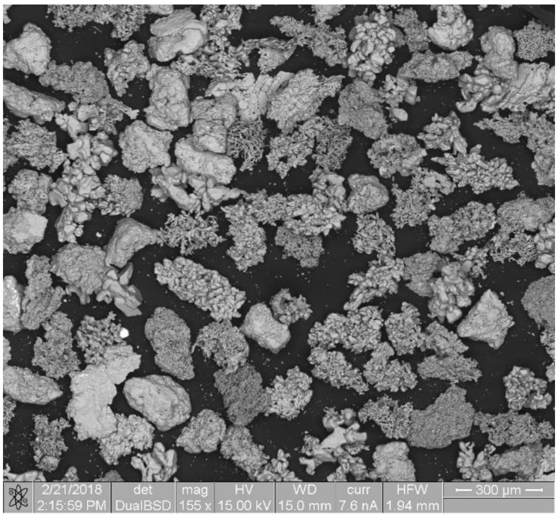

Figure 2. SEM micrograph of starting powder

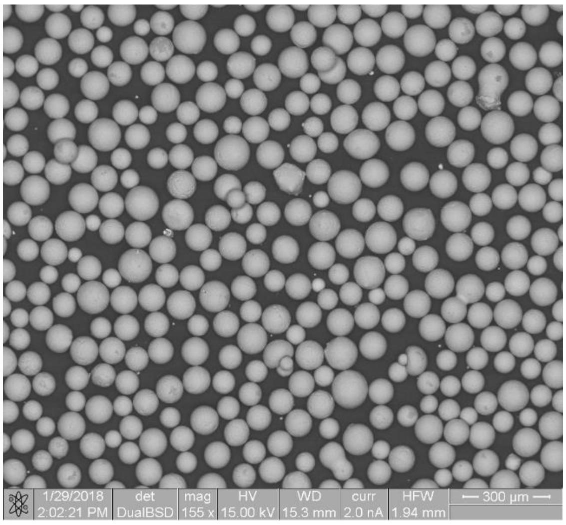

Figure 3. SEM micrograph of spheroidised powder

The density of the starting powder was *ca.* 4.3107 g/cm3 while that of the treated powders were 0.16 - 2.25% above that of the starting powder. The densification was random and did not follow a linear pattern, as a result, the spheroidised powder was mounted and polished to observe the internal morphology of the particles. The morphology of the polished particles are shown in Figure 4. It can be clearly seen from that the internal of the particles varied from being completely solid, to having small void and to being hollow. The flowability of the treated powder was significantly improved. It took *ca.* 34.8 s for 50 g of the treated powder to flow through a Hall flow meter with a 2.5 mm orifice, while the starting powder took *ca.* 103 s

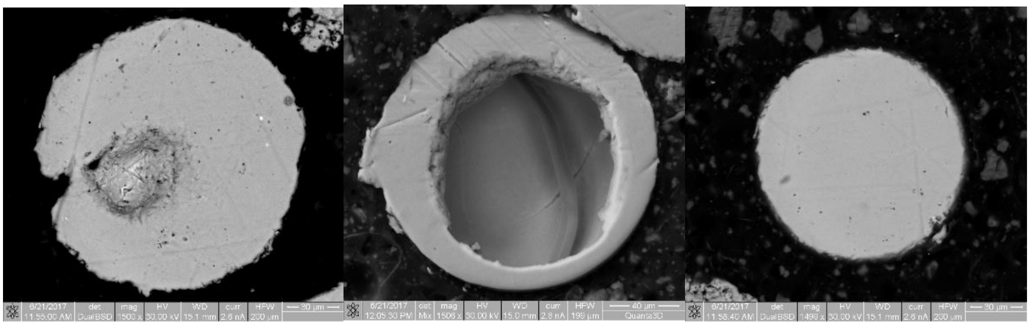

Figure 4. SEM micrographs of the polished spherical particles

The spheroidisation ratio and the fraction evaporated as functions of specific energy input are illustrated in Figure 5. The spheroidisation ratio and fraction evaporated increased with an increase in specific input energy. The minimum spheroidisation ratio achieved for powder with cross section size range of 150-180 µm at the minimum allowed power level (9 kW) was *ca.* 35%, while the fraction evaporated was *ca.* 5.5%.

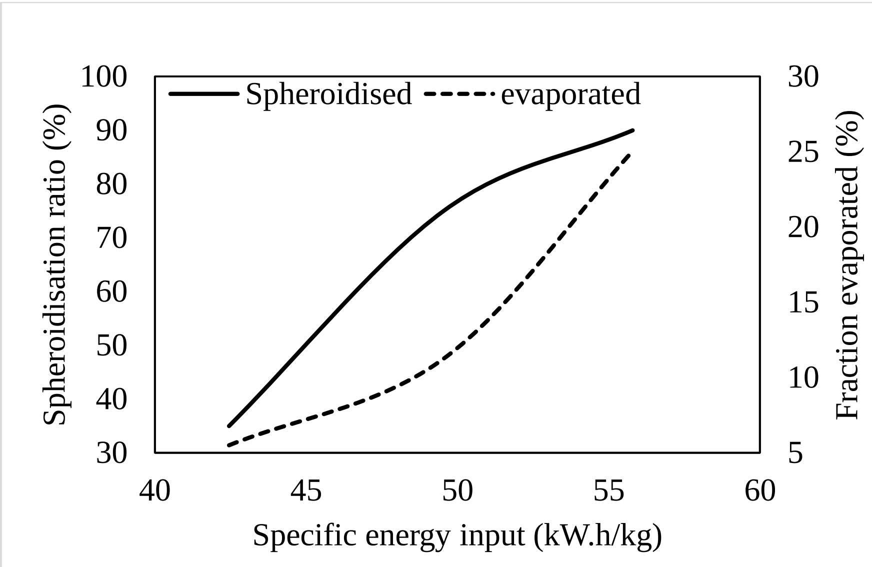

Figure 5. Spheroidisation ratio and fraction evaporation as function of specific energy input.

4. Conclusions

This study highlight the competency of Necsa in the area of spheroidisation, as it was clearly illustrated with the spheroidisation experiment of titanium metal. From these experiments it was learned that spheroidisation does not only improve the morphology of particles but also densify the particles which will result in a higher loading capacity for both 3D printing and plasma spraying.

6. Acknowledgements

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5. References

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