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EXPERIMENTAL RESULTS CONCERNING THE INFLUENCE OF FLOW-CONDITIONERS ON THE FLOW AND PACKING OF ALLUMINIUM POWDERS

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ABSTRACT

The flow time and the apparent density of powders are very important for the flow process through pipeline and for a good filling of a matrix. The main goal of our research project contains a lot of experimental results and interpretation concerning these aspects.

The paper shows some results and interpretation regarding the flow-conditioners, which in our case are the addition of nano-powder and the mixing process. Experimental had demonstrate that using an optimal combination between this two conditioners can to obtained an decreasing of flow time and an increasing of apparent density, benefic effects for the flow and packing of metallic powders.

Keywords: powders, nano-powders, flow-conditioners, flow-meter

1. INTRODUCTION

As mentioned before in the literature review flow and packing properties of a metal powder are both very important parameters. They influence the behaviour of the powder during die filling not only on the "hopper to die" sequence but also inside the die.

A powder with good flow properties will flow faster from the filling hopper thus giving a faster pace to the pressing process. Also a greater mobility of the powder particles associated with good flow will allow the powder to efficiently fill the die by occupying the entire space inside the die and leading to a better homogeneity of the pressed body.

The packing of powders as defined by the apparent density is also important as the apparent density gives the amount of powder flown into the die at the end of the die loading cycle. A higher apparent density involves fewer voids left between the powder particles and thus a better green density at the end of the pressing cycle.

Poor flow and packing properties of Aluminium powders have been identified as two of the most important problems impending the industrial scale fabrication and use of aluminium P/M parts. Other factors like particle size and particle size distribution, particle shape and particle surface roughness have a marked effect of the flow and packing. The subsequent section presents the effect of changing particle size, particle size distribution, particle morphology on the flow and packing properties of two grades of Aluminium powders with different characteristics made by different atomization gases (e.g. nitrogen and air). The effect of particle spheroidisation on the flow and packing properties of Aluminium powder and the use of nanosize particles as flow aids have been investigated.

The use of nano-sized flow conditioners as new alternative method to improve the flow properties with minimal cost addition was tried.

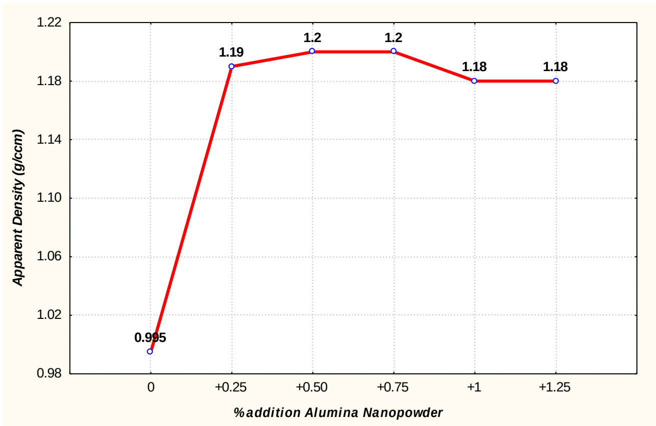
Alumina and Aluminium nanopowders were mixed in different proportions with three different size fractions of air atomized Al powders in order to study the effect that different types of nanopowder have on the flow and packing properties of each size fraction and also to determine the optimal percentage of addition.

Experiments were also carried out in order to determine the effects that mixing conditions on the flow and packing properties of powders containing nanopowder flow conditioners

2. EXPERIMENTAL RESULTS

In order to study the efficiency of increasing flow an packing properties of two different nanopowder flow conditioners and to determine the optimal level of addition relative to each size fraction, different percentages up to 1.25% with 0.25% increments of alumina and aluminium nanopowders were mixed for 10 minutes at 45 rpm together with 100 g of -45, (+45-75) and (+75-150)µm size fractions.

Figure 1 shows the effect of different percentages of alumina nanopowder addition to 45 µm size fraction. As little as 0.25% addition made the powder to flow with a flow time of 123 seconds and increased the apparent density from 0.995 g/cm^3 to 1.19 g/cm^3. Further addition had a deleterious effect on the flow time which increased to 130 seconds. Apparent density initially increased to



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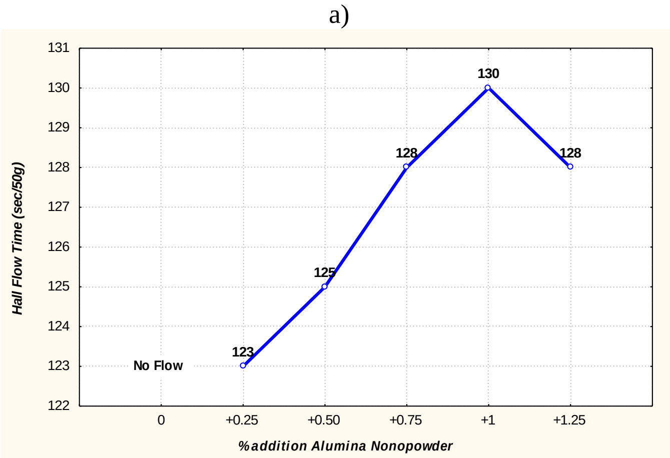

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Fig. 1. Effect of addition of alumina nanopowder on the (a) apparent density and (b) flow time of -45µm size fraction air atomized Al powder

1.20g/cm^3 but then dropped back to 1.18 g/cm^3.A similar trend could be observed in Figure 2, which shows the effect of different percentages of alumina nanopowder addition to (+45-75) µm size fraction.

A decrease in flow time from 87 seconds to 74 seconds accompanied by an increase in apparent density from 1.05 g/cm^3 to 1.16 g/cm^3 was observed for 0.25% alumina nanopowder addition. Further addition up to 1.25% increased the flow time to 80seconds and decreased the apparent density to 1.09g/cm^3.

The effect of mixing air atomised Al powder with 0.25% alumina nanopowder at 45 rpm, in a Turbula mixer, on the flow time and apparent density is presented in Figure 3. Flow time decreased from 83 seconds to 76 seconds and the apparent density increased from 1.076 g/cm^3 to 1.16 g/cm^3 after the first 10 minutes of mixing. Further mixing did not produce any significant change up to 480 minutes of mixing when flow time started to increase to 84 seconds and finally reached a value of 104 seconds and 0.92g/cm^3 apparent density after 720 minutes of mixing.

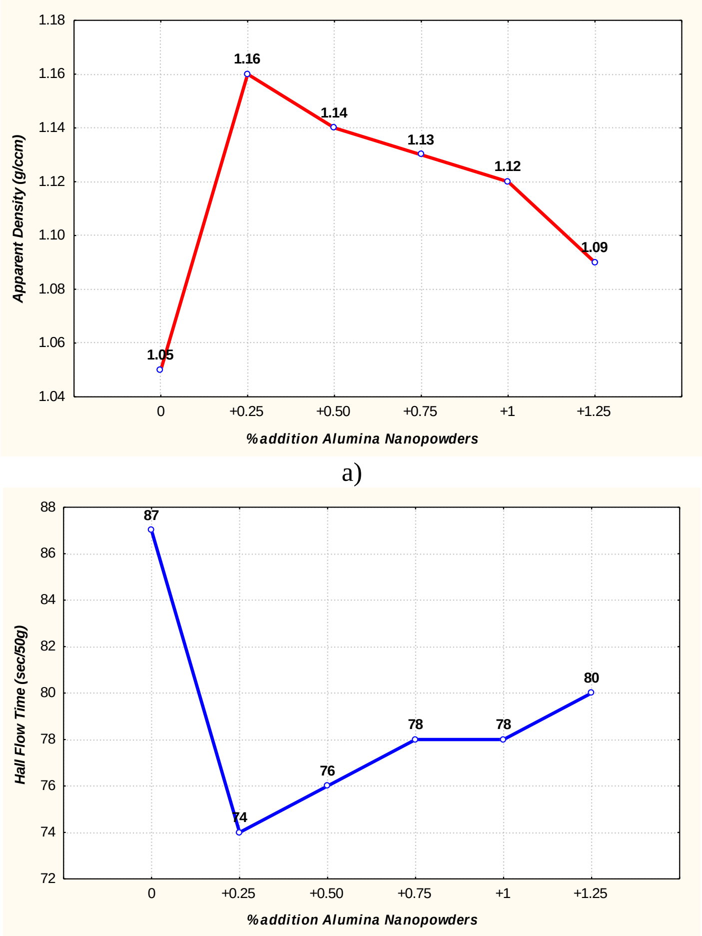

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Fig. 2. Effect of addition of alumina nanopowder on the (a) apparent density and (b) flow time of (+45-75) µm size fraction air atomized Al powder

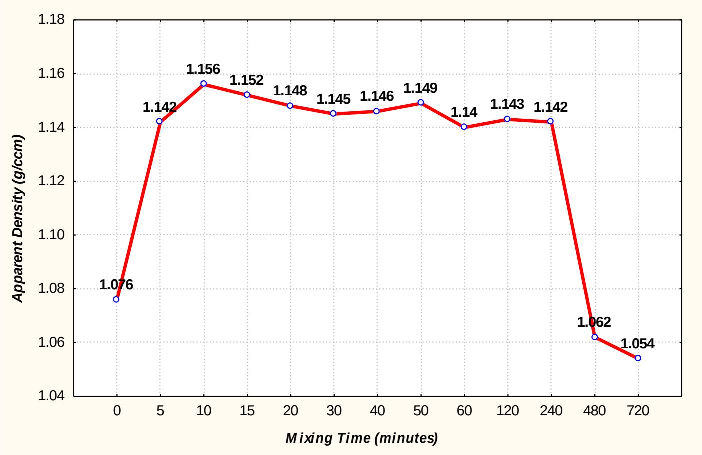
Greater mixing speed (101 rpm) of 0.25% alumina nanopowder addition to air atomized Al powder produced a similar effect but with an earlier occurrence of events as shown in Figure 4. Flow time decreased from 83 seconds to 75 seconds and apparent density increased from 1.076 g/cm^3 to 1.16 g/cm^3 after the first 10 minutes of mixing. However, after 240 minutes of mixing flow time increased to 82 seconds followed by “no flow” state and an apparent density of 0.93 g/cm^3 after 360 minutes of mixing.

In order to study the efficiency of increasing flow an packing properties of two different nanopowder flow conditioners and to determine the optimal level of addition relative to each size fraction, different percentages up to 1.25% with 0.25% increments of alumina and aluminium nanopowders were mixed for 10 min at 45 rev/min together with 100 g of under 45, (+45-75) µm and (+75-150) µm size fractions.

Figure 1 shows the effect of different percentages of alumina nanopowder addition to -45 µm size fraction. As little as 0.25% addition made the powder to flow with a flow time of 123 seconds and increased the apparent density from 0.995 g/cm^3 to 1.19g/cm^3. Further addition had a deleterious effect on the flow time which increased to 130 seconds. Apparent density initially increased to 1.20 g/cm^3 but then dropped back to 1.18g/cm^3.

A similar trend could be observed in Figure 2. which shows the effect of different percentages of alumina nanopowder addition to (+45-75) µm size fraction. A decrease in flow time from 87 seconds to 74 seconds accompanied by an increase in apparent density from 1.05 g/cm^3 to 1.16 g/cm^3 was observed for 0.25% alumina nanopowder addition. Further addition up to 1.25% increased the flow time to 80seconds and decreased the apparent density to 1.09 g/cm^3.

The effect of mixing air atomised Al powder with 0.25% alumina nanopowder at 45 rpm in a Turbula mixer on the flow time and apparent density is presented in Figure 3. Flow time decreased from 83 seconds to 76 seconds and apparent density increased from 1.076 g/cm^3 to 1.16 g/cm^3 after the first 10 minutes of mixing. Further mixing did not produce any significant change up to 480 minutes of mixing when flow time started to increase to 84 seconds and finally reached a value of 104 seconds and 0.92 g/cm^3 apparent density after 720 minutes of mixing.



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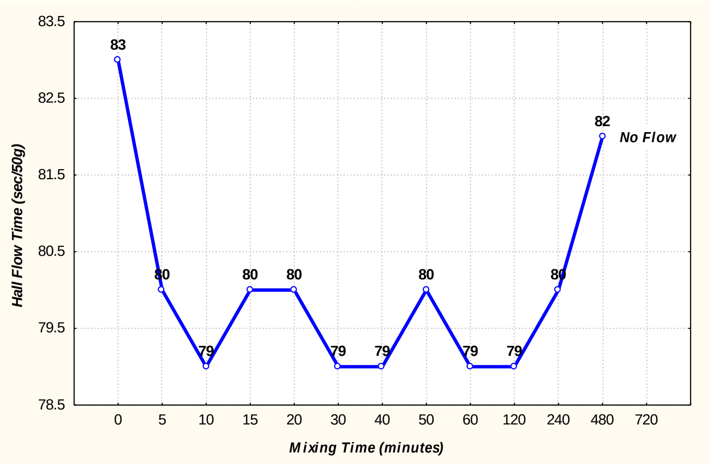

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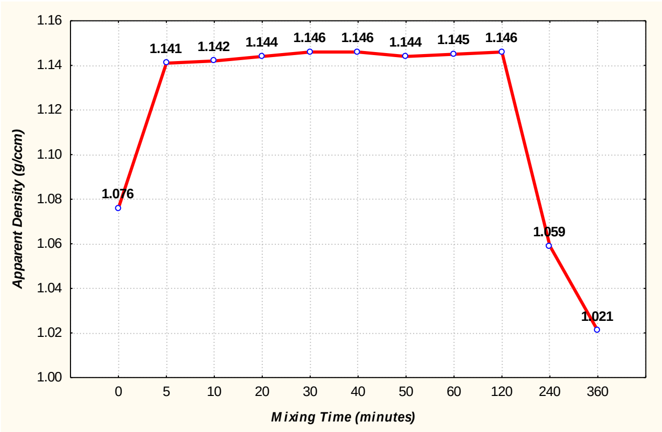
Fig. 3. Effect of mixing time @ 45 rpm on the (a) apparent density and (b) flow time of 0.25% aluminium nanopowder addition to air atomized Al powder

Greater mixing speed (101 rev/min) of 0.25% alumina nanopowder addition to air atomized Al powder produced a similar effect, but with an earlier occurrence of events as shown in Figure 4. Flow time decreased from 83 seconds to 75 seconds and apparent density increased from 1.076 g/cm^3 to 1.16 g/cm^3 after the first 10 minutes of mixing. However, after 240 minutes of mixing flow time increased to 82 seconds followed by "no flow" state and an apparent density of 0.93 g/cm^3 after 360 minutes of mixing.

The effect of mixing time at a constant speed of 45 rpm in a Turbula mixer on the flow time and apparent density of 0.25% aluminium nanopowder treated air atomized Al powder is presented in Fig. 3. Flow time decreased from 83 seconds to 79 seconds and apparent density increased from 1.076 g/ccm to 1.156 g/ccm after the first 10 minutes of mixing. Further mixing did not produce any significant change up to 480 minutes of mixing when flow time started to increase to 82 seconds and eventually "no flow" condition and 1.054g/ccm apparent density were reached after 720 minutes of mixing.



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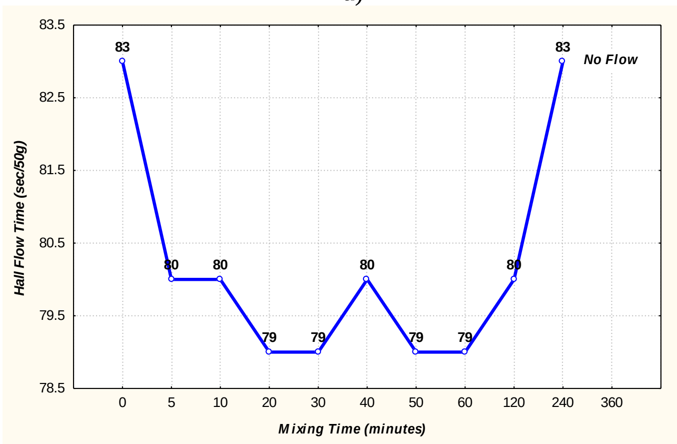

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Fig. 4. Effect of mixing time, at 101 rev/min on (a) the apparent density and (b) the flow time of 0.25% aluminium nanopowder addition to air atomized Al powder

Greater mixing speed (101 rev/min) of 0.25% aluminium nanopowder addition to air atomized Al powder produced a similar effect but with an earlier occurrence of events as shown in Fig. 4 and very similar to the behaviour of alumina nanopowder treated powder shown before. Flow time decreased from 83 seconds to 80 seconds and apparent density increased from 1.076 g/ccm to 1.142 g/cm^3 after the first 10 minutes of mixing. However, after 240 minutes of mixing flow time increased to 83 seconds followed by "no flow" state and an apparent density of 1.021 g/cm^3 corresponding to 360 minutes of mixing.

In order to determine and explain the mechanism of improving the flow and packing properties of powders by addition of nano flow conditioners like alumina or aluminium nanopowders and also the events that take place during mixing for extended times, high resolution SEM imaging was used to study samples of powder subjected to mixing for 10 min, 30 minutes and 120 minutes, at a 101 rev/min in a Turbula mixer. Pictures were taken from two different perspectives to show the reduction in overall size of agglomerates with mixing time.

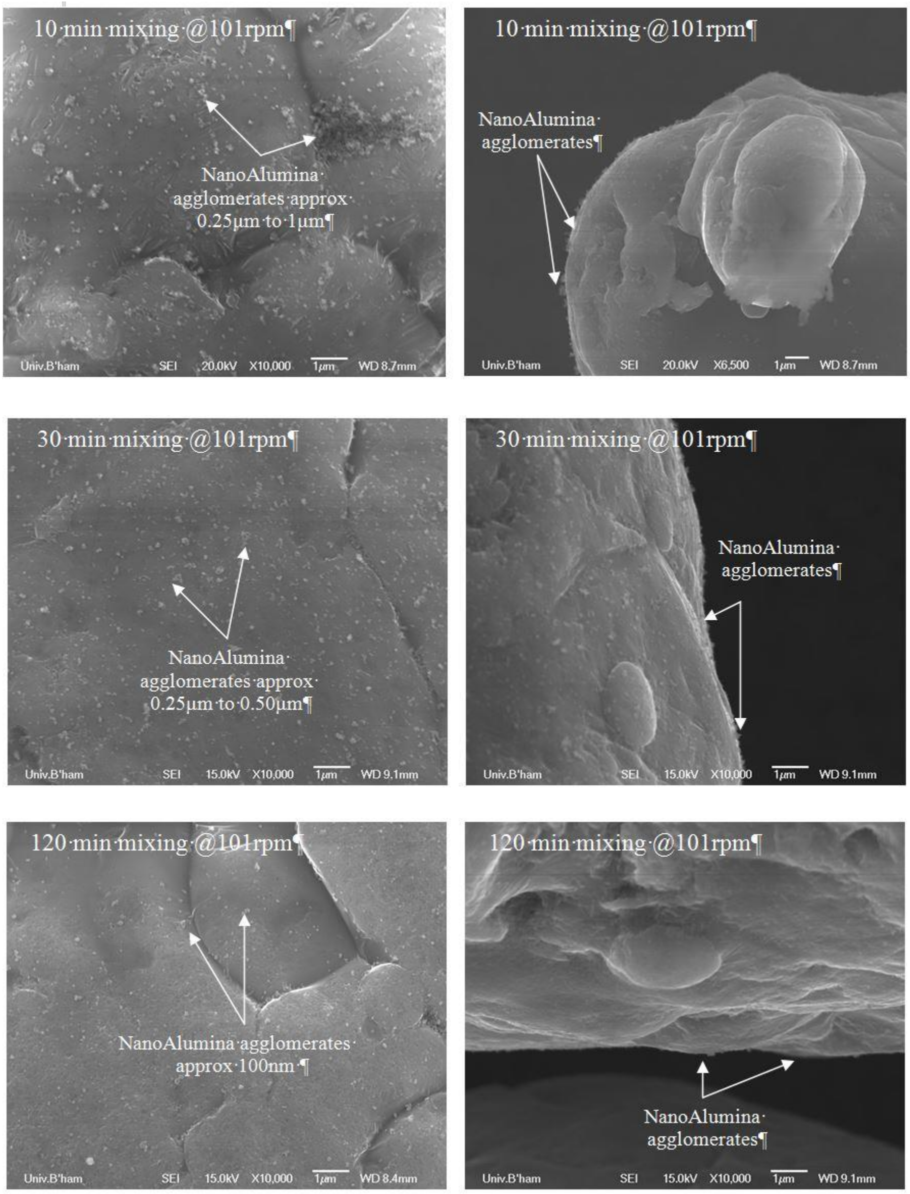

Fig. 5. SEM micrographs showing nano-alumina agglomerates on the surface of Al powders

Figure 5 shows alumina nanopowder agglomerates present on the surface of the powder, from two different perspectives, namely, perpendicular and tangent to the particle surface.

Mixing for 10 minutes leds to the formation of 0.25 μm to 1 μm agglomerates, distributed with a large random spacing on the surface of the particle. Also, the edge of the particle observable in the right column of pictures shows that the height of the agglomerated is having approximately the same value of 0.25 μm to 1 μm.

Mixing for 30 minutes slightly reduced the size of alumina nanopowder agglomerates to an approximate diameter between 0.25 μm and 0.50 μm and led to a more uniform coverage of the surface with nano particles. The edge of the powder particle shows that the agglomerates reduced their height as a result of longer mixing time.

It is believed that the improvement in flow and packing is associated with nano powders agglomerates acting like spacers between the particles and thus reducing the amount of inter-particle attraction. Mechanical impacts during mixing reduce the height of these agglomerates and the inter-particle attraction is restored and sometimes increased.

Summarizing, it was found that addition of nanopowders like alumina and aluminium have a beneficial effect on the flow and packing of air atomized Al powders.

Alumina nanopowder was found to be a more effective flow conditioner as compared to aluminium nanopowder. However, it appears that the mechanism responsible for improvements in flow and packing is irrespective to the material used but rather influenced by the ability of that material to form and maintain agglomerates.

3. CONCLUSIONS

As mentioned in the previous sub-sections, particle size distribution manipulation and mechanical spheroidisation of powder particles by mechanical milling can both be very useful methods on improving or even better, tailoring the flow and packing properties of Al powders. A disadvantage of these methods is that they all introduce supplementary steps to the production cycle like sifting/blending different size distributions and/or mechanical spheroidisation with negative implications on the final cost of the powder. As a result of that, a new approach was required.

Another method to reduce the flow time and increase the apparent density is to reduce the amount of Wan Der Waal force especially when fine or very fine powders are involved. The stimulus for the present study was the work of Meyer *et al.* /15/ who showed that flow properties and apparent density can be improved by mixing relatively fine powder (20μm mean size corn starch powder) with nano-sized powder of different nature and in different proportions.

The mechanism for such improvement is that nano-size agglomerates formed on the surface of the bigger powder are acting as spacers and thus reducing the Van Der Waals force which is direct proportional to the distance between the particles.

It was suggested that the ability of a nano-material to act as a flow conditioner is independent of its chemical nature /15, 16/. However, the size of nano-materials as well as their tendency to form agglomerates is dependent on the kind of material and/or the method of manufacture.

The above discussed work did not give any indication about the effect of such addition on the flow and packing properties of powders having an irregular shape and a high level or surface roughness since the corn starch powder used in the study had a perfect spherical shape with a smooth surface.

The effect of adding nanopowder flow conditioners on the flow and packing properties of a larger range of particles in terms of size, as well as determining the optimal percentage of addition, required further investigation. Further addition had a deleterious effect on both apparent density and flow time most probably due to an increase in the inter-particle attraction associated with nanoparticles. Larger amounts tend to create a continuous coat of nano-particles very similar to the bridging phenomenon with a negative impact on particle mobility. For all of the size fractions the apparent density and flow time followed the same trend.

It is needs to be mentioned that using nano-particle as flow conditioners has a more pronounced effect for the fine particles as compared to coarse particles. This is normal since Van der Waals forces are too weak to play an important role in the flow and packing of coarser size fractions. During the experiments it became apparent that mixing in a Turbula mixer of powders containing nano flow conditioners like alumina and Aluminium nanopowders can have a marked effect on the flow time and apparent density.

In summary, it was found that addition of nanopowders like nano-alumina and nano-aluminium have a beneficial effect on the flow and packing of air atomized Al powders when added to a maximum of 0.25 wt% proportion.

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