Ignition and inertization of metal powder waste

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Abstract

This study is inspired by a concrete industrial problem concerning the disposal of metal powder waste, which constitutes a hazard source because of its tendency to ignite violently. The purpose of this work is to study the mechanisms of metal (mainly aluminum) combustion, in order to identify the best inertization technology. After that, the goal is to optimize the inertization conditions for subsequent industrial applications. The development of standardized procedures to evaluate the hazard of the waste before and after treatment is also part of this study.

Introduction

Several manufacturing processes produce metal powder waste, which are hard to recycle due to their oxidized state. Handling and disposal of this waste can be hazardous, because of their tendency to ignite. Aluminum powder is particularly reactive, and its oxidation has the largest thermal effect [1]. Despite the presence of a protective oxide layer on the surface of the particles, ignition can occur due to electrostatic charges [2] or reactions with water [3]. The aim of this study is to identify the best technology to render the particles inert, in order to reduce or eliminate the hazard related to their handling and storage, that will be applied on an industrial scale. Using a protective coating to avoid ignition, while viable to preserve the powder for subsequent use [4], is not of economic interest when dealing with powder waste, and it has been proven by industrial experience to not be completely effective in preventing combustion during long periods of storage. This translates into choosing as inertization technology an oxidation of the particles, conducted in a controlled way. While several technologies exist to achieve this inertization, not all of them are economically viable when dealing with metal powder waste, where the aim is to make the waste safer, and not to recover it. Inertization with air, moist inert gas, steam and liquid water has been considered in this study.

There is also the need for a simple and reliable ignition test, in order to evaluate the hazard of the waste both before and after the treatment.

Materials

The material being considered, a sample of which is represented in Figure 1, comes from several industrial manufacturing processes. It is constituted of irregular particles, with a wide size distribution, and it is heterogeneous in nature, containing small amounts of nickel, magnesium and iron, while the majority is constituted by aluminum.

Figure 1: A sample of the metal powder waste

The material has been characterized by a chemical analysis, and a granulometric and morphological distribution. The oxidation state of the powder, while of interest, is hard to obtain due to the difficulty in the reduction of the protective layer (mainly Al_2O_3). A literature value of 4 nm (typical for oxidation of aluminum in air at ambient temperature) has therefore been considered for the initial thickness of the oxide layer.

Ignition tests

A series of standardized tests to evaluate the propensity to ignite, and therefore the requirement for an inertization process and its subsequent effectiveness, have been developed. These tests need to be reliable and easy to perform from an industrial standpoint. The procedures identified as viable in this study are:

- Immersion in 40%NaOH solution (which solubilizes the protective oxide layer, exposing the nascent metal below it), measuring the temperature increase (and from it, calculating the heat flow, and therefore the metal quantity through its heat of reaction)
- Combustion front propagation velocity, when exposed to a forced ignition (open flame)
- Reactivity in air under increasing temperature, measuring the ignition temperature (higher temperature means a thicker oxide and therefore a more inert material). An example of this technique, and its reproducibility on the same material, is shown in Figure 2.

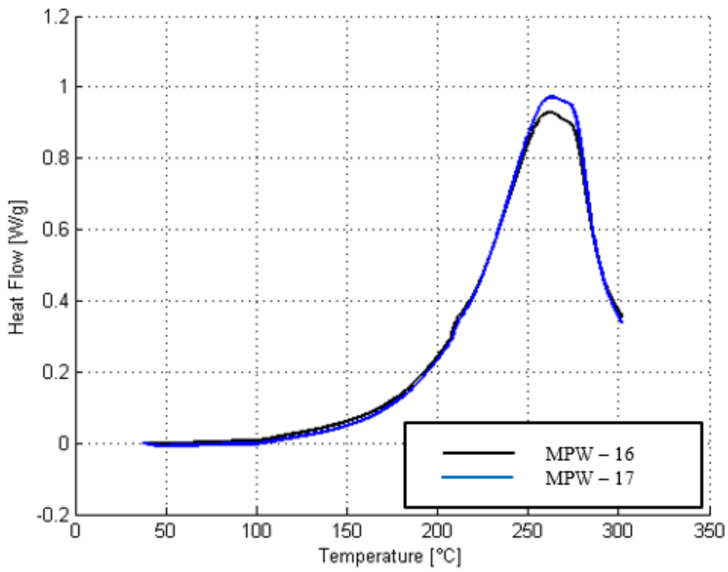

Figure 2: Reactivity in air

Inertization tests

Several techniques are being tested to identify the optimal technology to use on an industrial scale for the inertization of metal powder waste. Reaction with liquid water, although cheap and easy to control, has been discarded because of the long ignition time (~ 50h), which could only be reduced with strong acids or bases, but the resulting solution would then be expensive to dispose of. The material is being treated in a packed bed with air, moist inert gas (nitrogen) and steam, at various temperatures. After treatment, the sample's oxidation is evaluated through the weight increase corresponding to the oxidation, before being subjected to the ignition tests detailed above.

Conclusions

A series of simple, reliable procedures have been developed for the evaluation of the hazard, both before and after treatment.

This inertization study phase is still in an early stage, precluding any hard conclusions on the best industrial technique to be used for the inertization of the material. Once identified, further testing is expected in order to optimize the operating conditions (flowrate, temperature, residence time) for its industrial application.

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