SYNTHESIS OF RECYCLABLE ALUMINUM FOR THE PRODUCTION OF METALLIC PIGMENTS BY HIGH ENERGY MILLING

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Abstract

Metallic pigments have been developed because of their properties of covering and anti-corrosion protection. Aluminum is a great material to manufacture metallic pigment due to the lamellar format of particles. The lamellar morphology increases the resistant of penetration creating a protection to the surface. The covering morphology of aluminum powder is known as “flake”. In addition, it is possible to recycle aluminum to produce pigment with high quality because of its capacity of recycling repeatedly. This work will focus on the development of metallic pigment using aluminum scrap by high energy milling. The use of reduced particles improves the ability of abrasion resistance, hardness and covering. The ideal morphology was reached by the control of milling parameters such as rotation and time of milling. The flake was produced by decreasing the parameters in high energy mill. The evolution of the particles was achieved in planetary milling using ethil alcohol 95% as additive. The additive was responsible to control the cold fusion in milling process. The material morphology and the size reduction in the different parameters of process were analyzed by Scanning Electron Microscopy (SEM). The model of SEM was Tescan microscope a VEGA 3 LMU. The results indicate that the pigment was diluted in resin epoxy and applied in surface to check its adherence and homogeneity.

Keywords: Aluminum scrap, high energy milling, Nano pigment, metallic paint

1. INTRODUCTION

In recent days, researches have been developing the capacity of recycling materials. The importance of these studies is the amount of waste generate by the society. It was developed different ways to reuse these wastes and contribute to the society and environment. The recycling of materials like aluminum reduces waste, save energy, provides revenues for recyclers and protect the environment [1]. The source of aluminum could be cans, automotive components, plates, windows frame etc. There is relevant growing of investment in recycling of aluminum cans from different type of industries like juice, soft drink and beer. In addition, recycling of aluminum cans have an important social role, generating employment in companies like logistic, materials and outsources [2]. One of the most advantages of aluminum is the capacity of recycling repeatedly, keeping the original properties [1]. Another relevant advantage of recycling aluminum is the reduction of mining exploration that produce damage outputs for the environment [3].

Recycling of aluminum has been studied hardly to explore all advantages possible. To begin the process of recycling, it is required the preparation of materials eliminating impurities. So it is necessary to remove any ferrous metal [1]. After this, the aluminum is ready to be transformed in a news product.

One product that has been used in large scale is the metallic paint that can be manufactured by pigment based on recycling aluminum. This kind of pigment provides long-term corrosion protection for the surface expose to aggressive environments. In addition, this metallic pigment could have specific characteristic as waterproofing [4]. The corrosion of structure is responsible for a lot of damages, generating losses like reduction of durability, necessity of maintenance and risk of accident [5]. Thus, technique to avoid corrosion is very important for any kind of process.

Considering these advantages, there are a lot of investment and researches to development of metallic pigments. The idea of manufacture metallic pigment based on recyclable aluminum involves two relevant issues: evolution of surface technology and sustainable processes. The metallic paint works as a barrier, protecting the surface and mitigating the corrosion [5].

2. EXPERIMENTAL PROCEDURE AND MATERIALS

The main raw material used in this research was aluminum from recyclable cans. In addition, the titanium dioxide can include more covering properties for the pigment. Titanium dioxide is regularly used to production of pigment due to protection of surface from UV degradation and it is inert photochemically in specific crystalline structure, the rutile [6].

This research has focused on the development of metallic pigment based on aluminum scrap by high energy milling process. The reason of this paperwork was the production of pigment that provides high capacity of protection for different type of surface [7].

The development of the pigment includes different steps. Firstly, aluminum from cans has been cut out in small pieces (about 10x10mm) by a regular scissors. The aluminum material should be cut to optimize the milling process. The pieces of aluminum scrap were submitted to high energy milling. The powdered aluminum was obtained by processing the aluminum material in the stainless steel container with 3 L of capacity and filled by 2.5kg of steel ball with 10mm and 5mm of diameter as shown in **Figure 1**. This step was necessary to obtain powdered aluminum. The parameters of this step (first milling) were 1200rpm during 2 hours. The powder resulting from first milling was submitted to an additional high energy milling using different parameters of rotation and time. The second milling was done to acquire the flake, ideal morphology for the pigment. The rotation was reduced to 300rpm during 1 hour to obtain the flake morphology. The flake was analyzed by Scanning Electron Microscopy (SEM) to evaluate the morphology.

Figure 1 High energy mill

Two further milling was conducted in planetary mill to obtain the flake in micro and nanodimentions. The reason of this additional milling was the increase of anti-corrosion properties. Nanoparticles can prevent the direct contact of the corrodent with the surface [8]. The powder reduction was reached by the planetary milling using ethil alcohol 95% as additive. The proportion of the alcohol was about 5% of the container volume. This additive was able to control cold fusion generating the reduction of the particle [9]. The parameters used in planetary milling were 159 rpm during 2 hours and 200 rpm during 1 hour.

To evaluate the evolution of the material, it was collected the pigment from the planetary mill every 30 minutes. All results were analyzed by Scanning Electron Microscopy (SEM) to confirm the morphology of the aluminum powder. To conclude, the pigment was added in epoxy resin and some additions to verify the paint’s properties. The paint was manufactured in a high rotation mixer and applied in metal surface previously prepared by sanding. The preparation of surface implies to obtain mechanical bonds through roughness and cleaning. The cleaning is necessary to remove impurities such as contaminants and oxidations. The roughness is responsible for increasing of contact surface and adherence [10].The pigment was diluted in resin epoxy in the proportion: 70% resin and 30% pigment. The preparation of paint has involved pre-mixing, dispersal and completeness. These processes are necessary to guarantee the quality of paint and homogeneity. [11,12]. In addition, it was added 35cm³ of catalyst to finish the manufacture of the paint.

3. RESULTS AND DISCUSSION

3.1. Pigment

Aluminum was chosen because of the high ductility that can transform its morphology [13].This transformation can be done by specific parameter of high energy milling processes. To obtain covering properties, the particles are transformed in lamellar shape, the flake [13]. Thermogravimetric Analysis has shown that the use of aluminum as metallic pigment increases the resistance in terms of degradation. The aluminum provides reduction of weight loss [11]. In addition, high purity aluminum has been used in large class of metallic pigment due to better resistance of humidity and exterior environment result [16].

The **Figure 2** shows up the powder's morphology after the first milling process. This process was done to transform pieces of aluminum to powder. It is possible to analyze that the powder is not the flake yet. The format of particles is not lamellar and there is no covering property

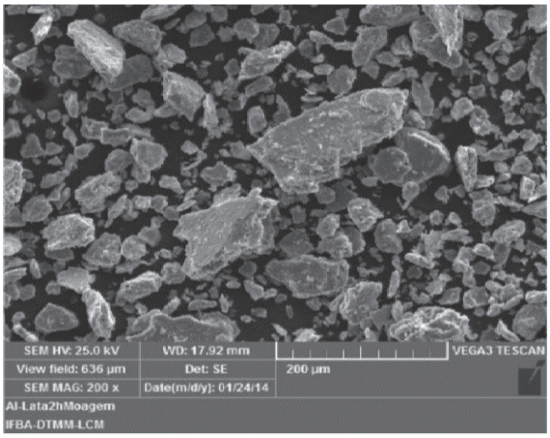

Figure 2 SEM image showing particles submitted to horizontal mill

The **Figure 3** shows the flake morphology of aluminum obtained by high energy milling. The reduction of parameters became the morphology of particles in a lamellar structure. This morphology is considered ideal for covering properties [13]. Previous experiments showed that the powder tends to change its dimensions in higher parameters. These changes cause losses of covering ability [11].

The use of reduced particle improves the performance of pigment such as abrasion resistance, hardness, strain-to-failure [14]. In addition, the nanopigment cans cover surface better than micro pigment [15].

The manufacturing of particles was done in two different parameters to evaluate the interference of the rotation in the morphology. The particle was evaluated in two different rotation. The analyses shows that the decrease of rotation can manufacture a better particles. In addition, it is possible to save energy.

The **Figure 4** shows the morphology of the particles submitted to 159 rpm in planetary milling during half hour with alcohol 95% as additive. It was possible to realize a considerable reduction of the size of particles. The additive was able to promote the reduction in the begin of the process. So it was concluded that this additive is really able to avoid the cold fusion in milling process. The analyzes in Scanning Electron Microscopy (SEM) cannot measure the size of particles because of crowding, however it was possible to conclude that the milling process in planetary with the additive is able to reduce the size of particles about nano and microdimensions.

The **Figure 5** represents the aluminum flake from the previous milling submitted to 159 rpm during 2 hours in planetary milling. It was possible to analyze a considerable reduction of particles around nanodimentions.

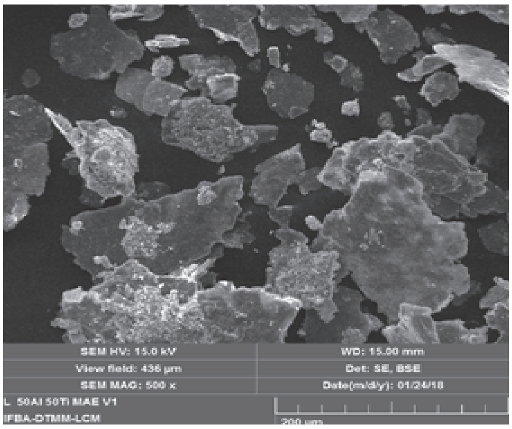

Figure 3 SEM image showing of the flake particles submitted to horizontal mill

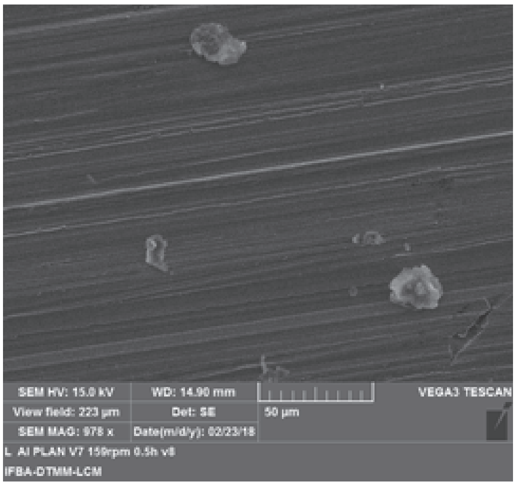

Figure 4 SEM image showing particles submitted to planetary mill

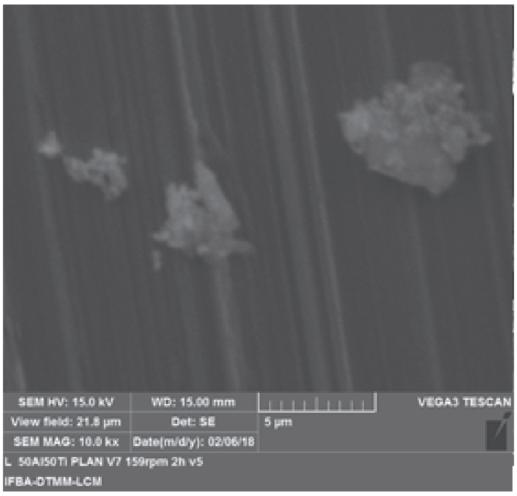

Figure 5 SEM image showing particles submitted to palnetary mill

The **Table 1** shows up the evolution of reduction of particles in planetary milling. It is possible to identify s particles of metallic pigment reduced after 2 hours of milling. So it was concluded that this process described can reduce the size particle according to the time of milling.

Table 1 Size of particles collected from planetary mill in different time of milling

Time of milling	Rotation- 159 rpm			
30´	13.22 µm	16.32 µm	21.5 µm	24.03 µm
1h	9.41 µm	9.85 µm	11.64µm	15.62 µm
1h 30´	2.08 µm	3.16 µm	3.27µm	5.44 µm
2h	**860 nm**	1.06 µm	2.77µm	3.74 µm

3.2. Metallic paint

The analyses of the paint's performance (pigment and resin epoxy) were done in a metallic surface. The paint has shown great adherence in surface as shown in **Figure 6**. In addition, it was observed a homogeneous dilution.

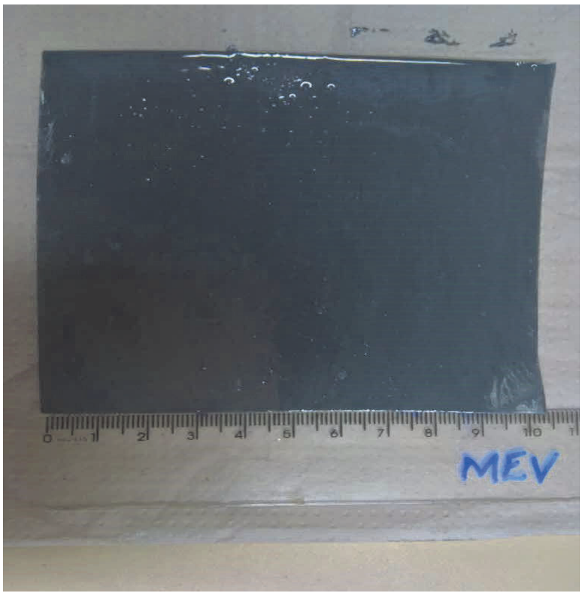

Figure 6 Paint manufactured by metallic napigment and resin epoxy in sanding surface

4. CONCLUSIONS

In this study, it was investigated the influence of the additives and parameters of milling to manufacture pigments. The ideal morphology to produce pigment, the flake, was reached through reduction of parameters of milling such as rotation and time. After that, the particles were reduced to increase the anticorrosion performance of the pigment. The additional reduction was possible by using ethil alcohol 95% as additive, since this solvent prevents cold fusion during the milling. The experiments show that the parameter of milling and additive can reduce the size of particle according to this study. The analyses in Scanning Electron Microscopy (SEM) have evaluated the evolution of the reduction of the sizes. The pigment was diluted in epoxy resin to check its properties such as adherence and homogenous in metallic surface. To conclude, the main reason of this study was to produce pigment with high performance from recyclable material such as aluminum cans.

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