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Fabrication of Al paste by ball milling

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1. Introduction

Aluminum pastes have been widely used in paint component for industrial application. In this study, the fabrication of aluminum paste by ball millng of Al foil was investigated. The factors related to the milling process such as milling time, oleic acid content, and weight ratio of mineral spirits/foil in the jar without lifter bars were studied. Also, the ball motion in jar with lifter bars during ball milling can be expected to be different to that in the jar without lifter bars. Ball motions in tumbler milling jar without and with lifter bars were also compared experimentally. Effects of lifter bars on main characteristics of milled aluminum flake powder and the degree of gloss of automobile paints made from these powders were also investigated.

2. Experimental

The 10 g of aluminum foil, 725 g of stainless steel ball with diameter of 16 mm, 3 wt.% of oleic acid as process control agent and 10 g of mineral spirits were charged in the horizontal container which was made of stainless steel and had length of 80 mm, inner diameter of 70 mm. The milling was performed for 60 h under rotation speed of 78 % of critical rpm. On the other hand, contents of oleic acid(0, 1.5, 3 and 5 %) and weight ratio of mineral spirits/foil (0, 0.5, 1, 2 and 3) were varied in wet ball milling process.

On the other hands, the horizontal stainless steel container with lift bars were also prepared and filled with stainless steel balls as much as 50 % of jar volume. The milling jars were rotated under the different speeds and ball motions were observed by naked eyes and photographed simultaneously. The aluminum foils, 3 wt.% of oleic acid as milling agent and mineral spirits were charged abovementioned jar. The millings were performed for the different times under different rotation speeds corresponding to cascading mode and cataracting mode.

The mean size and water covering area of powders were measured by the particle size analyzer (Coulter LS130) and DIN standard 55923, respectively. Water covering area of flake powder was defined by water covered area per gram of aluminum powders coated by iso-butyl alcohol after cleaning by acetone. Thickness and aspect ratio of aluminum powder were calculated according to the formulas of 1/(Al density 2.7 g/cm3x water covering area) and mean powder size/thickness, respectively. The shapes of aluminum flake powders were also checked by optical microscopy and scanning electron microscopy (SEM). Aluminum paint was prepared by mixing of Al paste 3.8%, thinner 24.2% and lacquers 72 % and painted on steel or glass plate. The degree of gloss was measured by Horiba IG-320 Gloss checker.

3. Results and discussion.

Water covering area of flake powder is increased with milling time due to the increase of specific surface area of milled powder. Flake thickness of powder is decreased continuously by milling up to 30 h. As milling time increases to 30 h, aspect ratio of flake powder is increased to maximum due to high degree of flake.

For the mineral spirit content below 50 %, foil was not milled because sliding motion of balls by lubricant effect between balls and wall of container. As weight ratio of mineral spirit and foil increase over 100 %, foils were milled to powders with mean powder size 15 ~ 20 ㎛ irrespective of mineral spirit content due to reduced lubricant effect. After milling for 30 h with mineral spirits/aluminum foil of 100 ~ 300 %, content of mineral spirits in aluminum paste was controlled as 35 % below by vacuum drying for pigment application.

Oleic acid are usually added to aluminum paste 3 ~ 5 % for controlling non-leafing character and milling agent. It is impossible to mill the foil without oleic acid to produce powder due to coagulation of foils. As content of oleic acid increases from 1.5 % to 5 %, mean size of powder milled for 30 h is decreased drastically due to prevention of coagulation.

On the other hands, when rotation speed of conventional milling jar (without lifter bar) is below 80 rpm (75 % of critical rpm), balls slides in the jar due to high gravity of balls. In the cases of lifter bars in the jar, balls move as cascading mode and cataracting modes at 40 rpm (37 %) and 60 rpm (56 %), respectively.

Aluminum foils were charged and ball-milled in jar without lifter bar and with lifter bars in order to investigated the efficiency of lifter bars on milling of Al foil . Millings were conducted under the rotation speeds of jar causing cascading and cataracting motions of balls. As increasing ball-milling time from 6 to 22.5 h, the mean powder size decreases from 26 ~29 to 15 ~19 ㎛ and water cowering area increases from 18,900 ~ 21,200 cm^2/g up to 27,800 ~ 29,870 cm^2/g, correspondingly.

The variations of mean powder size with milling time were nearly same in jar without lifter bars irrespective of cascading and cataracting mode. Mean powder size after milling for 15 h ~ 22 h 30 minutes in the jar with lifter bars in cascading mode was lower than in cataracting mode.

The degrees of gloss after painting using aluminum paste are 26-28.5 on base of 100 in the case of glass plate. The quality of painting appearance was good, suggesting for application to car paint by using paste milled with foil.

4. Conclusions.

It is possible to make Al pastes by wet ball milling of aluminum foils. The milled powder size was also greatly affected by oleic acid and mineral spirits. 2 ~3 wt.% of oleic acid as additive, weight ratio 100 ~300 % of mineral spirits to foils were verified to be under the range of optimum content. Lifter bars have the roles of restricting of sliding motion and helping centrifugal motion. Under the low rotation speed of jar with lifter bars, fine flake powder can be prepared as similar shape and size to that milled in jar without lifter bars under the high rotation speed. The aluminum paste produced by wet ball milling of aluminum foil can be applied to painting to automobile body.