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Vibration grinding - An approach for secondary use of refuse metallic aluminium

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ABSTRACT

An investigation for recycling of refuse metallic aluminum grade AE having more than 99.5 % Al content has been studied by means of vibration attrition. The refuse metallic aluminum is produced by the cable manufacturing sector. The factors responsible for rendering the metallic aluminum into powder one, have been studied under normal batch lab-scale conditions. The following factors have been under consideration: quantity of the material to be ground; grinding media type; influence of surfactant addition etc. The conditions influencing the obtaining of aluminum powder with different particle shape have been established.

Key words : *Vibration grinding, Metallic aluminum, Recycling*

INTRODUCTION

The aluminum metal is the native metal most abundantly met in nature. Its chemical and physico-mechanical characteristics are an obstacle for its pure state wide use in different fields. However this situation is counter balanced by the large acceptance of the aluminum alloys in variety of industrial branches. The introduction of one or more chemical elements, even in negligible quantities renders the aluminum properties useful for desired application. Most commonly met are the alloys of the type - Al-Mg, Al-Cu and Al-Si[1].

The most common route for recycling and re-use of the different aluminum alloys grading 99.5 % and more in Al is via pyrometallurgical means. Great part of the obtained aluminum is transformed by different ways into a powdered aluminum having grain shape and size suitable for the respective customers[2]. Among the consumers are the powder metallurgy, the manufacturing of furnace-blended anti-friction alloys - substitutes of the tin bronze, the manufacturing of dyes and corrosion resistant coatings, electrode coatings, additives to some explosives, manufacturing of porous-concrete building materials and others.

As like the pyrometallurgy, the various methods for aluminum powdering are rather costly processes. The vibration grinding offers and alternative means for obtaining of powdered aluminum from waste aluminum alloys or metallic aluminum grading in aluminum above 99.5 %. The powder aluminum obtained could be directly utilized in industrial sectors which either does not impose strict requirements concerning the impurities or by means of proper blending one could obtain standard in chemical composition and grain size aluminum powders suitable for the given customer. The aluminum powder obtained directly from waste materials by means of vibration attrition provides an economic alternative to the traditional recycling.

EXPERIMENTAL

Materials and Equipment

For the purposes of studying the vibration powdering of scrap metallic aluminum different types of aluminum source have been used:

- scrap aluminum from cable manufacturing having diameter (ID) 3 to 6 mm, cut into small rods with 15 to 30 mm length;
- aluminum shavings from metal finishing machines;
- stripes cut waste aluminum foil with 0.5 mm thickens and 20 to 30 mm length.

A laboratory type vibration mill with 350 cm^3 cylindrical working chamber has been employed. Vibration parameters have been kept constant: frequency - 35 Hz, amplitude - 6 mm.

The following materials have been tested as a working media:

- riffle-type rod weight - 560 gram;
- riffle-type rod weight - 700 gram;
- smooth surface rod from WC weight - 1700 gram;
- smooth surface rod from WC weight - 2850 gram;
- lenses from WC with 42 mm diameter which weight 1150 grams when the chamber is 80 % filled.

Method of Investigation

The method of investigation aims to evaluate the influence of several factors upon the metallic aluminum grindability at fixed vibration parameters. The factors studied were:

- working media type;
- quantity of the material under investigation;
- vibration milling duration;
- type and quantity of the added surfactant.

Vibration grinding results have been evaluated by checking the yield of minus 0.071 mm size class. The grinding process kinetics has been monitored by interruption of the grinding process at regular intervals (5 or 10 minutes). The grinding media and the material have been removed from the chamber. After visual inspection of the ground material the yield of 0.071 mm under size class has been determined. The oversize is placed back inside the milling chamber and the grinding process is re-started. The above procedure has been repeated several times until grinding process was totally completed.

RESULTS

Table 1 presents the results from the visual observation of the vibration grinding monitoring when aluminum scrap cable (5 mm ID, 15-30 mm length and 30 grams weight) was under investigation. The influence of the various grinding media has been studied. The following abbreviations have been used to indicate the changes taking place within the system:

A - slight deformation (the initial shape could be recognized);

B - strong deformation (the initial shape could not be recognized);

C - non-uniform spherical shape;

D - uniform spherical shape;

E - leaven shape (connected small spheres);

F - size reduction (reduction of the mean diameter of the ground material);

G - no change (no change in the mean diameter of the ground material);

H - enlarging of the material (enhancing the mean diameter of the ground material);

I - sticking of the ground material onto grinding media and chamber lining.

Table 1 : The results from the visual observation of the vibration grinding by the various grinding media

Grinding media	Milling time, min.							
	5	10	15	20	25	30	35	40
riffle rod 560 g.	A	B	C	C	D	D	-	-
riffle rod 700 g.	B	E	D	D	G	G	H	H
smooth WC rod 1700g.	B	E	D	D	I	I	-	-
smooth WC rod 2850g.	B	D	F	I	I	-	-	-
lenses WC	A	I	I	-	-	-	-	-

Table 2 summarizes the results from the visual observation of vibration grinding of aluminum scrap cable (5 mm ID, 15-30 mm length, different quantity). Grinding was carried out in riffle rods media. The same abbreviations as explained above have been used.

Table 2 : The results from the visual observation of the vibration grinding by different quantity of aluminum scrap

Quantity of the material to be ground, g.	Milling time, min.							
	5	10	15	20	25	30	35	40
10	E	F	F	G	I	I	-	-
30	B	E	D	D	G	G	H	H
50	B	F	V	F	H	H	-	-
100	A	B	C	D	D	D	-	-

The influence of the shape of the aluminum lumps subjected to vibration grinding has been evaluated using three different scrap aluminum products: cable wastes, shavings and aluminum sheet pieces. The chemical composition of the cable scrap and the shavings have been determined by semi-quantitative spectral assay. The results obtained are presented in Table 3.

Table 3 : The results from the semi - quantitive spectral assay

Product	Assay, %									
	Al	Mn	Cr	Cu	Zn	Fe	Ni	Co	Mo	Mg
Cable scrap	99.5	0.005	0.1	0.003	0.1	0.2	0.01	0.003	0.0005	<0.1
Shavings	99.5	0.003	0.07	0.002	0.03	0.3	0.002	0.005	0.0003	<0.1

The grinding process type both for the cable scrap and the aluminum shavings has been more or less identical. The grinding time for the foil scrap has been kept 5 minutes longer, in which period material rendering into non-uniformed spheres and leaven-shape forms takes place. After that time the type of grinding is similar to the one for the cable scrap and metallic shavings. These phenomena have been observed when riffle rods (700 g.) have been employed as grinding media and the material to be ground was always in amount of 30 gram.

Table 4 illustrates some experimental results from cable scrap vibration grinding with riffle rods (700 gram) with the presence of organic reagents.

Table 4 : The results from aluminum cable scrap vibration grinding with organic reagents

Surfactant type	Quantity	Yield of class - 0.071 mm[%] for grinding time, min.					Type of Al powder obtained
		10	20	30	40	Total	
Diesel oil	2 drops	2.6	4	5	5.3	16.9	gray, luster free
Diesel oil	5 drops	3.1	4.65	5	6	18.75	gray, luster free
Trans. Oil	2 drops	3.3	5	8	9.6	25.9	gray, luster free
Trans. Oil	5 drops	3	4	6.3	10	23.2	gray, luster free
Oleic acid	2 drops	3	4	6	10.5	23.5	dark grey
Na oleate	1 g.	6	11	14	17.7	48.7	dark grey
M	0.5 g.	3.6	16.3	22.5	19.7	62.1	glossy, luster
M	0.6g.	3.3	17.3	29.6	39	89.3	glossy, luster
M	4x0.2g	4	11.3	32.6	36.3	84.2	glossy, luster
without reagent	0	3.3	1.3	1.6	1.6	8.9	metallic luster

DISCUSSION

The presented investigation in direction of vibration grinding of scrap aluminum with metal content above 99.5% has suggested that the process is technically possible and economically feasible, provided the optimum amount of material and the proper type and shape of the grinding media are chosen. The commonly met sticking of the aluminum onto milling media and chamber lining could be avoided if a properly sized riffle rod grinding media is employed. The experimental results have suggested that both the weak as well as the strong shock impacts have a negative impact upon the vibration grinding of the metallic aluminum. The application of the crushing impacts, associated with the lens-type media is also non-suitable.

The observation method we have chosen for monitoring the vibro grinding process of the material under study has confirmed the following relationship. The raw lump material experience deformations as a result of the shock vibration impacts and regardless of the initial material shape finally is transformed into irregular spheres. These forms are further ground and are transformed into uniform shape spheres with small diameters and leaven-shape formations as well. When the vibration grinding is carried out further on without rejecting the finest size class reached - i.e. 0.071, 0.1 mm etc., one could observe aggregation of the fine spheres with uniform shape and high mechanical strength. The grinding kinetics when the yield of 0.071 mm size class is taken into account under normal conditions is low - around 9 %.

Significant changes in the milling kinetics are observed when surfactant added in air media was used. The following surfactants were studied with the aim of enhancing grinding efficiency: diesel oil, transformer oil, oleic acid, sodium oleate and reagent M. It was established that the use of the first three reagents is leading to 2 to 3 times higher yield of 0.071 size class. The sodium oleate increases grinding from 5 to 6 times, while the reagent M - 10 times. The aluminum powder produced depending on the reagent employed is predominately flaky without luster in gray color. It is worth to acknowledge the effect of the step addition of the reagent M in a dosage of 0.2 grams each 10 minutes. The aluminum powder obtained in this instance is characterized by luster flakes, which alters their mean diameter from coarse to fine grain size in due grinding continuation without loosing their glossy look.

The shape of the metallic aluminum lumps in the material subjected to grinding in surfactant assisted environment does not influence the type and quantity of the final powder product.

CONCLUSION

The vibration grinding is a convenient means of obtaining aluminum powders suitable for various industrial sectors, customers and standards. Maintaining both the shape of the particles and the granulometric characteristic of the powder produced in a desired direction has been possible. The production of aluminum powder under the studied vibro grinding conditions offers the following advantages:

- guaranteed of obtaining aluminum powder with pre-determined granulometric composition and particle shape;
- simplified technological flowsheet in comparison to the available powdering methods;
- no metal losses.

The metallic aluminum recycling by means of vibration grinding is a convenient way of rendering the waste aluminum product into useful material.

REFERENCES

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