Analysis of Ball Milled Aluminium Alloy 7068 Metal Powders

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Abstract

Fabrication of a ball mill and subsequent analysis of ball milled AA7068 metal powders is the main objective of this present work. To facilitate this purpose, it is essential to design and fabricate a smaller and compact ball mill. Consideration of the various design parameters of the original larger counterpart plays an essential role for the successful design. This paper deals with the design, fabrication of the compact ball mill for blending and mixing of both metallic and the non-metallic powders. AA7068 metal powder was milled using the fabricated ball mill for various operating hours and the same was analysed. Particle size analyzer was used to find the size of the particles. Scanning Electron Microscopy (SEM) was done for analysis and EDAX was done to confirm the presence of AA7068 powder particles. Results indicated that with the increased duration of ball milling the powder particle size was reduced. Hence, by altering the duration of milling, pure or alloy or ceramic powders can be formed with desired properties up to near-net shape as required.

Keywords — *Ball Mill, Alloys, Powder Metallurgy, SEM, EDAX*

I. INTRODUCTION

Powder Metallurgy is the process of manufacturing of components from metal powders. Production of metal powders is the initial step of the process. The powder characteristics such as size shape and surface area has a significant impact of the final finished product. There are several methods of producing powders and the selection of the particular method depends on the requirement. In many applications, the quantity of raw materials fed into the ball mils is of prime importance. This quantity has a major effect on the production and its parameters as demonstrated by Luan Weilei et al [1]. It is one of the parameters to be controlled in many industries, such as cement industries. These machines are also found widely in ore grinding facilities. However, the machines show low efficiency with high energy consumption. Hence, even a small improvement on the performance of the grinding process, can have a significant impact in the operating cost of the plant and optimize energy resources. The low efficiency can be equated with many reasons. One among these is the optimum filling condition. This can be determined by measuring electrical variables of the motor that drives the ball mill. Analysis of the supply current or instantaneous power demand is a promising alternative to be considered for improving the energy efficiency of the equipment as explained by M. G. Melro, J. M Cano et al [2]. Juan Tisza-Contreras and Huber Nieto-Chaupis have explained that there are several parameters that are strongly interconnected and have strong correlation with each other. These parameters affect the output particle size. The method of powder production is decided mainly by the final properties required in the component [3]. The load parameter inside the ball mill is one among the key factors affecting the production ration and the quantity of the grinding process directly. Ball mills produce sound mechanical vibrations and acoustic signals. Jian Tang et al suggest that methods such as Hilbert Vibration Decomposition (HVD) can be used to determine the vibration level [4]. J.Corrochano, M. Lieblich and J. Ibanez have conducted an experiment to find the effect of ball milling on the microstructure of powder metallurgy aluminium matrix composites reinforced with $MoSi_2$ intermetallic particles [5]. In the experiment, hot extruded Al-Mg-Si composites reinforced with 15% volume of $MoSi_2$ intermetallic particles. The relation between reinforcement size, ball milling time, and matrix structure and particle distribution were investigated. Their result proved that increasing the ball milling time with homogeneous distribution gave rise to higher tensile properties, without the loss of ductility and also, reduces the matrix grain size to sub-microscopic level. After certain duration, ball milling has no/ little effect on the particle size, independent of the initial size of the reinforcement. E. Haghshenas Jazi, G. Borhani and R. Esalmi Farsani have used ball milling technique for the preparation of Al-Fe / TiB_2 nano-composite powder and subsequent heat treatment [6]. Mechanical Alloying (MA) was used to synthesize Al-Fe/TiB_2 Nano composites using aluminium, ferro-titanium and boric acid as raw materials under Argon atmosphere in an attritor ball mill. Then, the milled powders were heat treated. The microstructure obtained was investigated by X-ray diffraction and Scanning

Electron Microscope. Results showed an average grain size of 45nm. Cheng Qi-ming et al have showed that control measures on the ball mill can be obtained up to satisfactory extent using model free adaptive control method based on grey prediction model [7]. Dynamics of the closed loop of a ball mill were investigated by C. R. Costea et al [8]. Robust PID controllers were used for fine tuning to obtain precise control. Simulation results confirm that the approach of using PID control provides higher performance. This paper gives details of the performance of a compact ball mill fabricated. Powders of Aluminum 7068 were milled by using this technique and the powder size was determined after certain duration. The powders were analyzed using SEM and EDAX.

II. EXPERIMENTAL SETUP

The ball mill is designed for both compactness and maximum efficiency. The important component of the ball mill is the cylindrical drum. The powder to be milled is fed into the cylinder along with the grinding media i.e., the balls. The material selected for the cylinder should have sufficient hardness and of suitable thickness. The cylinder is subjected to large amount of impact due to the grinding action of the balls. As the ball mill designed is only for research purpose, Stainless Steel 304 (Brinell Hardness 201) was chosen as the material. Cylinder with Outer Diameter of 114 mm and Internal Diameter of 97mm was designed for the purpose. Large thickness of 8.5mm was used to provide sufficient strength. Stainless Steel balls were used as the grinding media, to mill the powder. The ball mill should be made to run at the proper speed to provide high efficiency. So, the selection of transmission system in the ball mill also plays a vital role. The layout of the arrangement is as shown in the figure. The electric drive motor operates at a high rpm of about 1440 rpm. Hence, the speed reduction of 12 to 18 times is mandatory. This speed should be reduced in stages. A V-belt drive (A38) is used to provide the initial speed reduction initially reduced to 150 rpm with a speed reduction ratio of 9.67. The second speed reduction from 150 rpm to 101 rpm was obtained with the help of a gear drive. The shaft from the gear is connected to the cylindrical drum. The drum rests on rollers which are supported on the frame. This facilitates free rotation of the cylinder. The arrangement also reduces the vibration forces. The powder used for testing is AA7068 alloy with the following composition.

TABLE I - COMPOSITION OF AA 7068 ALLOY

Element	Percentage by Weight
Si	0.12
Fe	0.15
Cu	2
Mn	0.1
Mg	3
Cr	0.05
Zn	8
Ti	0.01
Zr	0.1
Al	Remaining

The analysis of the performance of the ball mill is done by measuring the particle size by Scanning Electron Microscope and the analysis of the components is done by Energy Dispersive X-ray Spectroscopy.

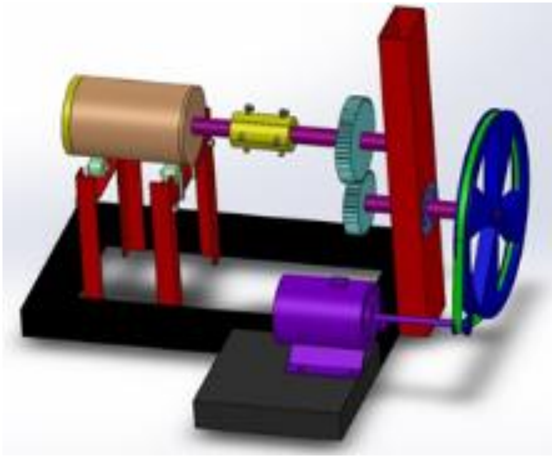

Fig 1: Designed Ball Mill

Fig 2: Fabricated Ball Mill

III. METHODOLOGY

The powders to be milled are fed into the cylinder of the mill, along with the grinding media, i.e., the grinding balls. The milling rate that can be attained is a function of the powder quantity in the net volume between the balls. This attains a maximum value, when the powder fill is 100% (i.e., when the powder completely fills the spaces between the balls). The speed of the mill also has a great impact on the milling rate. The milling speed should be adjustable. This is to ensure that the balls properly cascade and cataract and performs the operation in the required manner. The proportion of cascading and cataracting is dependent on the speed of rotation of the mill and the coefficient of friction of the charge material. The rate of milling is increased when the size of the balls used for grinding is increased. The maximum rate of milling is attained, when the size is sufficient for crushing the particles of the feed powder.

A. Forces Acting During Milling

The following forces usually acts on the material while milling,

1. Impact
2. Attrition
3. Shear
4. Compression

The striking of the powder particles with each other creates the force of impact. The rubbing action that exists between the two particles creates wear particles by the process of attrition. Shear occurs by the cutting of the particles and it finally results in fracture. The force of compression is due to the crushing of the particles by the balls used in the mill.

B. Critical Speed

Critical Speed of the mill is the speed of rotation at which the milling rate is maximum. If the slip of the charge against the mill chamber wall is assumed to be negligible, critical speed of rotation of the mill may be given by the formula,

$$N_c = 76.6 \sqrt{(1/D)} \qquad (1)$$

Where D = the mill diameter in feet

N_c= the critical speed of the mill in revolutions per minute.

The ball mill is designed and operated based on the calculations of the speed of rotation of the ball mill as shown below.

$$N_c = (60/2\pi) * (2g/D)^{1/2} \qquad (2)$$

Where

g = Acceleration due to gravity in m/s.

D = Inner diameter of the cylinder in m.

The Ball Mill is usually run at 70 – 80% of N_c. So we take the speed as 75% of N_c.

IV. RESULTS AND DISCUSSIONS

A. Particle Size

The ball mill was run at three fourth of critical speed (N_c) i.e. at 101rpm and the results obtained by milling of Aluminum 7068 alloy using the compact size ball mill is given in the table 2. By using this machine alloy powders of less than 1.7 µm size can be obtained. Alloy powders obtained are without any contamination.

TABLE II - RESULTS OBTAINED

Duration (Hrs)	Average Particle Size (µm)
0	3.280
20	2.347
40	1.785

These parameters are approximate and may not be valid for metal particles that tend to agglomerate (fuse together by welding).

The mill is highly efficient when it is run at the critical speed. Centrifuging action is found to occur, when the speed of rotation of the mill is higher than the critical speed. This is because, due to the increased speed, the balls rotate along the inner walls of the cylinder. This also results in inefficient grinding. Inefficient grinding also occurs when the mill is operated at a speed much lesser than the critical speed. In this case, the balls do not experience sufficient force to rise up against the cylinder walls and does not have necessary force to grind the powder feed.

To facilitate proper grinding of the particles, a proper speed range that is closer to critical speed is chosen. This speed is about 0.7 – 0.8 times of the calculated critical speed. At this proper speed, the balls rise up to certain height along the cylinder walls and then, fall freely to the bottom with sufficient force to grind the particles, resulting in good milling.

The size of the particles that can be formed depends on the duration of the milling. Initially, the particle size was measured to be 3.280 microns. After 20 hours of ball milling, the powders were 2.347 microns in size. There is a considerable reduction in the particle size during the interval. After 24 hours of milling, it is observed that there is a significant reduction in the size of the particle. Only a small difference in the reduction of the size of the particles was observed, when measured after 24 and 40 hours of milling. This indicates that there is a gradual decrease in the particle size reduction after a certain amount of milling time. The particle size measured after 40 hours of milling was 1.785 microns. Hence, it could be concluded that the size of the particles gets reduced more, when the mill is operated for longer duration up to the optimum duration. Beyond certain duration of ball milling no effect on the particle size is observed. The SEM and EDAX images of the powders obtained are also shown.

B. SEM Analysis

The fig. 3 shows the SEM micrograph of the AA 7068 which was taken before the ball milling. The fig. 4 shows the microstructure of the powder which was ball milled for 20 hours and it clearly shows the change particle size which was reduced to 2.347 microns. The fig. 5 shows the microstructure of the 40 hours ball milled powder which has a reduced size of 1.785 microns.

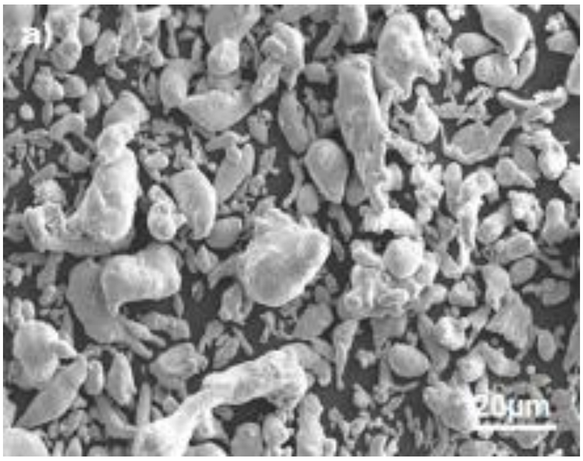

Fig 3: SEM Image of AA 7068 Powders before Milling

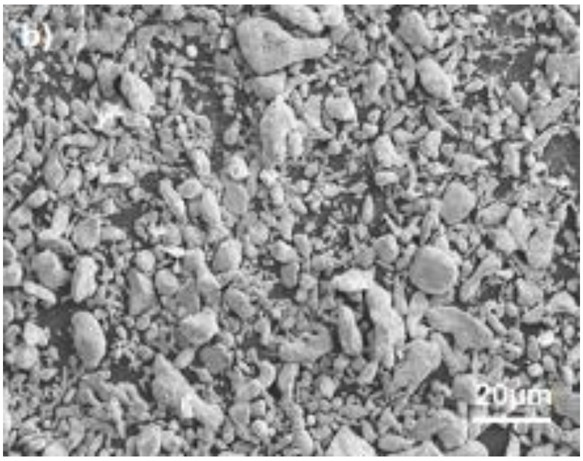

Fig 4: SEM Image of AA 7068 Powders after 20 Hours of Milling

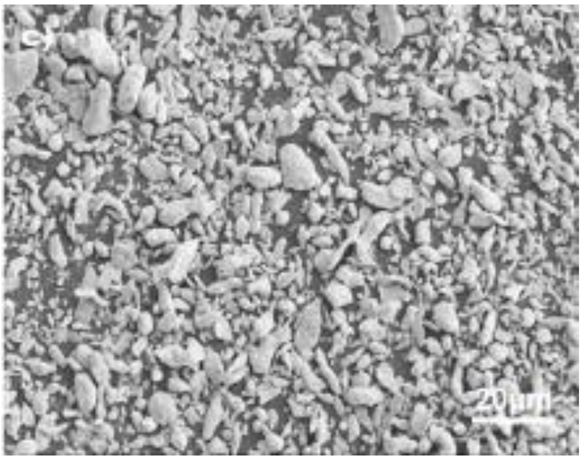

Fig 5: SEM Image of AA 7068 Powders after 40 Hours of Milling

C. EDAX

The following figures illustrate the EDAX pattern for AA7068 powder particles. The EDAX pattern in fig. 6 shows before ball milling. Fig. 7 and 8 shows the EDAX pattern after milling for 20 hours and 40 hours respectively, which confirms the presence of Al7068 powder particles.

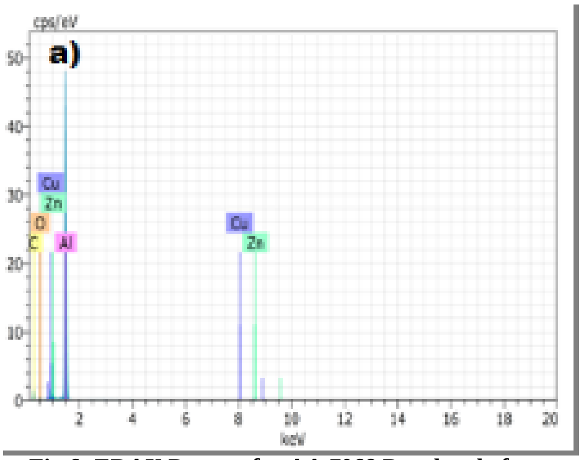

Fig 6: EDAX Pattern for AA 7068 Powders before Milling

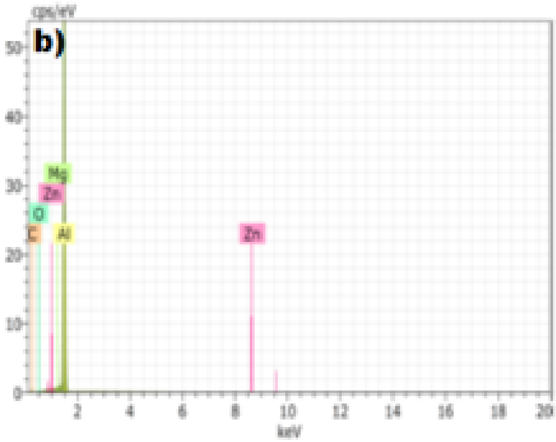

Fig 7: EDAX Pattern for AA 7068 Powders after 20 Hours of Milling

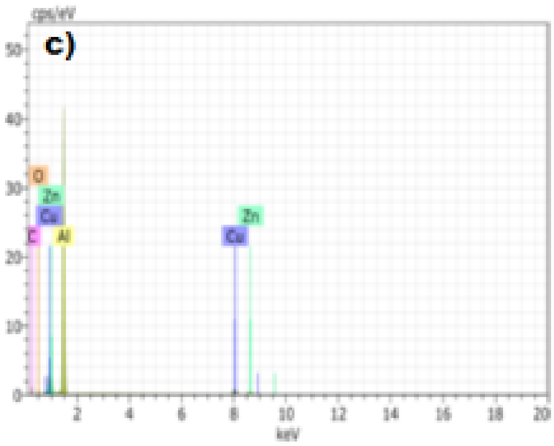

Fig 8: EDAX Pattern for AA 7068 Powders after 40 Hours of Milling

Some of the advantages of using this method are the ability to produce powders of both pure and alloyed metallic and non-metallic components with different compositions. The construction of this machine is simple and is of less noise. Balls, of different shape, size, and composition can be used for milling the powders.

This machine can be used for research purpose in powder metallurgy and also in small scale applications, where production of new composite structure requires powder formation and testing their characteristics.

V. CONCLUSIONS

A small size ball mill for mixing and blending the powders was successfully designed and fabricated. Particle size of the AA7068 powders was reduced from 3.280 µm to 1.785 µm for a milling period of 40 hours at a speed of 101 rpm. The SEM images show the reduction of particle size from course to finer size. EDAX image ensures the presence of AA7068 powder particles.

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