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Effect of Ball Milling for AA7068 Metal Powders for Variable Speeds

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Abstract— **Present work deals with design and fabrication of a ball mill for mixing and blending of metal powders. The ball milling was done for AA7068 metal powders for three different speeds at 150, 200 and 230 rpm and at different time durations such as 0, 5, 10, 15, 20 and 25 hours. Particle size analyser was used to find the average particle size of the particles. SEM was done to analyse the microstructure of the powder particles. The study revealed that the particle size has been reduced from 4.233 µm to 1.742 µm for 150 rpm, 4.233 µm to 1.548 µm for 200 rpm and 4.233 µm to 1.361 µm for 230 rpm for the duration of 25 hours and hence ball milling at variable speeds has a significant effect in reducing the particle size.**

Keywords: Ball mill, multi speed milling, powder metallurgy, blending

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 parameters that are strongly interconnected and have strong correlation with each other. These parameters affect the output particle size. These are determined by analysing the behaviour when subjected to disturbances. For this reason, a single powder production method cannot be used for all the applications [1]. There are several methods of producing powders and the selection of the particular method depends on the requirement. Ball mill is the most widely used machine for the production of powders in most of the industries. This quantity has a major effect on the production and its parameters [2]. 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. Hilbert Vibration Decomposition (HVD) can be used to determine the vibration level. An experiment to find the effect of ball milling on the microstructure of powder metallurgy aluminium matrix composites reinforced with $MoSi_2$ intermetallic particles [4]. 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 [5]. 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. Analysis of the supply current or instantaneous power demand is a promising alternative to be considered to improve the energy efficiency of the equipment [6]. This paper reports the effect of ball milling of AA7068metal powders milled at variable speeds with different time durations.

II. EXPERIMENTAL

A. *Design of Ball mill*

A ball mill can be made of any size. The smaller the size the efficiency is more. A ball mill primarily consist of motor, horizontal cylindrical container, V belt drive, stepper pulley. The whole setup is placed on a rigid frame. The frame should withstand the vibration and rotational forces of the ball mill. The motor is connected with the cylindrical container through the pulley and the belt. The motor runs at 1440rpm. The stepper pulley reduces the motor speed to the critical speed of the ball mill. The critical speed of the ball mill is 130rpm. The motor and pulley are connected by a first shaft. The cylindrical container and another pulley connected by a second shaft. The length of the cylinder should be 1.5 times larger than the diameter of the cylinder. The diameter and length of the cylinder is 95mm and 200mm respectively. The impact stresses are acts on the cylindrical wall so thickness should be more. Both the pulleys are connected by a V belt drive. The V belt has less slip and more power transmission. The cylindrical container should be made of a material which has high hardness and resistant to corrosion. So the mild steel

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is selected for the cylindrical container material.

The stepper pulley helps to run the ball mill at different speeds. The cylindrical container are filled with spherical stainless steel balls up to half of the container along with the metal powders. The diameter of the steel balls is 12mm. The container is placed above the rollers to give free rotation. The bearing is used to support the second shaft. This ball mill is applicable only for studies and research purposes. The whole setup of the ball mill design is shown in fig1. The composition of AA7068 powders were shown in Table I.

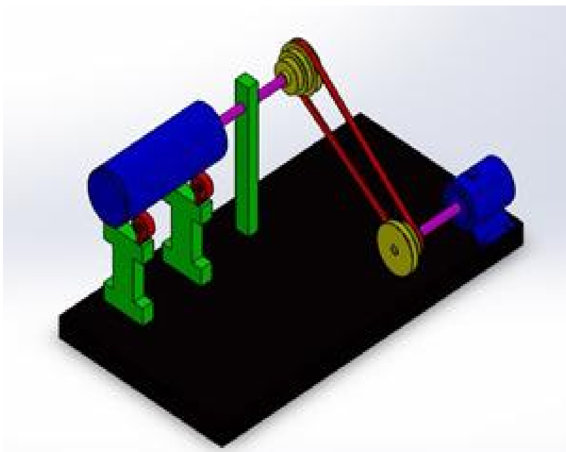

Fig 1. Ball mill arrangement

TABLE 1. COMPOSITION OF AA7068 (% BY WEIGHT)

Element	Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti	Zr	Al
Content	0.12	0.15	2	0.1	3	0.05	8	0.01	0.1	Bal

The AA7068 metal powders were milled for three different speeds at 150, 200 and 230 rpm and at different time durations such as 0, 5, 10, 15, 20 and 25 hours. SEM analysis was done to study the microstructure.

III. METHODOLOGY

A. *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,

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

Where 'D' is the mill diameter in feet

'N_c' is the critical speed of the mill in revolutions per minute.

Ball mill is a horizontal rotating steel cylinder. It grinds alloys to fine particles. The grinding is carried out by the pounding and rolling of a charge of steel balls carried within the cylinder.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.

Ball mills are a very efficient tool for grinding many materials into a fine powder. To use the mill, the material to be ground is loaded into the container which contains grinding media. As the container rotates, the material is caught between the individual pieces of grinding media, which mix and crush the product into a very fine powder over a period of several hours. Quite simply, the longer the Ball mill runs, the finer the powder will be. Ultimate particle size depends entirely on how hard the material is grinded and how long the ball mill is run.

IV. RESULTS AND DISCUSSION

A. *Particle size*

The ball mill runs at a speed of 150, 200,230 rpm for different time duration of 0, 5, 10, 15, 20 and 25 hours with an interval of 5 hours. The following results were obtained and shown in table II.

The size of the particles depends upon the speed of the ball mill and time duration of the milling.

TABLE II: AVERAGE PARTICLESIZE DISTRIBUTION

Duration (hours)	Average particle size powders µm		
	150 rpm	200 rpm	230 rpm
0	4.223	4.223	4.223
5	3.884	3.634	3.375
10	3.232	3.016	2.854
15	2.787	2.547	2.369
20	2.167	1.925	1.706
25	1.742	1.548	1.361

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The average particle size were measured on equal time interval of 5 hours. The ball mill runs at constant speed of 150 rpm which is the first speed. After 5 hours of milling operation the size of the particle is reduced to 3.884 µm. After 10 hours of ball milling, the particle size reduced to 3.232 µm and so on upto 25 hours. The milling is continued for 200 rpm and 230 rpm. The study revealed that the particle size has been reduced from 4.233 µm to 1.742 µm for 150 rpm, 4.233 µm to 1.548 µm for 200 rpm and 4.233 µm to 1.361 µm for 230 rpm for the duration of 25 hours After 30 hours of milling operation there was no significant reduction of particle size. [3] proposed a principle in which another NN yield input control law was created for an under incited quad rotor UAV which uses the regular limitations of the under incited framework to create virtual control contributions to ensure the UAV tracks a craved direction. Utilizing the versatile back venturing method, every one of the six DOF are effectively followed utilizing just four control inputs while within the sight of un demonstrated flow and limited unsettling influences.

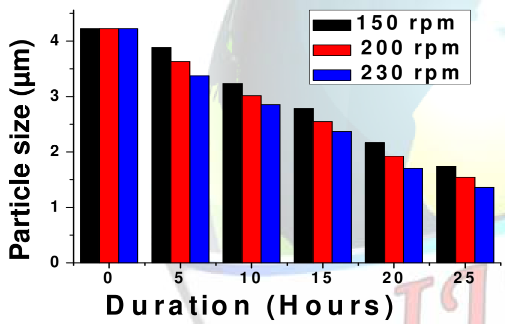


Fig 2. Average Particle size distribution for different time duration at variable speeds

B. SEM analysis

The fig 3a and 3b shows the SEM image of the AA7068 powders after milling for 25 hours at 150 rpm with lower and higher magnification respectively. The particles of irregular shapes were found. The fig 4c and 4d shows the SEM image of the AA7068 powders after milling for 25 hours at 200 rpm with lower and higher magnification respectively. The particle sizes were finer compared to fig 3a and 3b. The fig 5e and 5f shows the SEM image of the AA7068 powders after milling for 25 hours at 230 rpm with lower and higher magnification respectively. The particle sizes were finer compared to fig 3a, 3b, 4c and 4d. The fig. 5e shows the particle size of 1.361 µm.

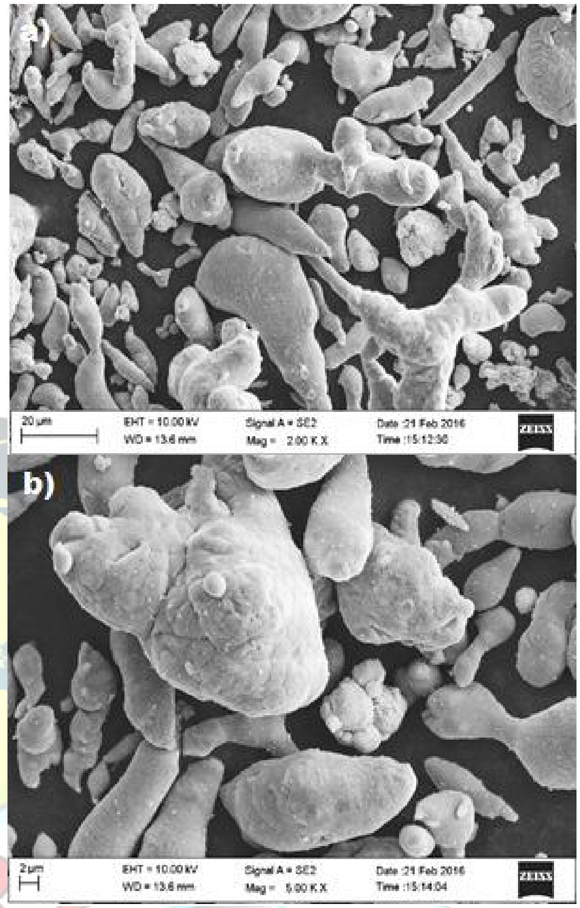
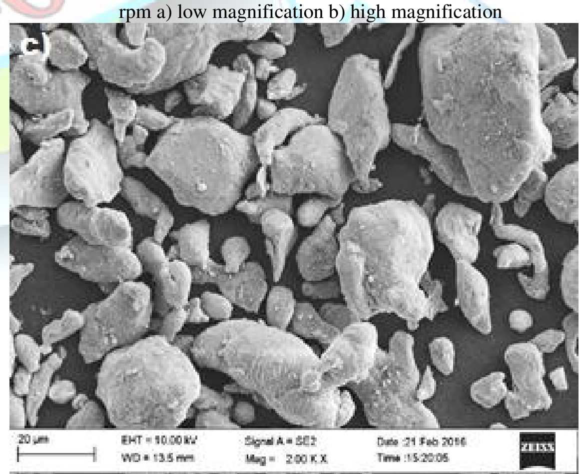


Fig 3. SEM images of AA7068 powders after milling for 25 hours at 150 rpm a) low magnification b) high magnification



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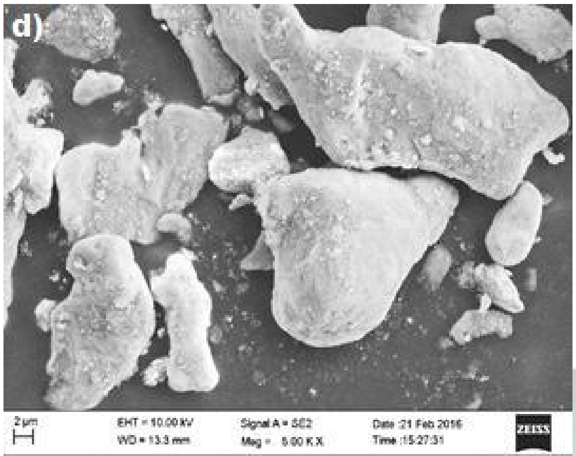

Fig 4. SEM images of AA7068 powders after milling for 25 hours at 200 rpm c) low magnification d) high magnification

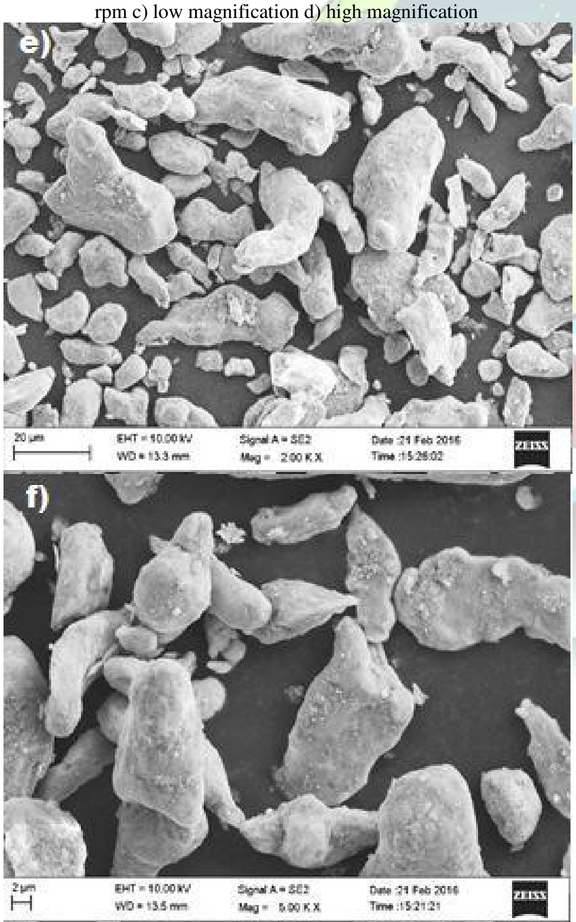

Fig 5. SEM images of AA7068 powders after milling for 25 hours at 130 rpm e) low magnification f) high magnification

V. CONCLUSION

A small sized ball mill for mixing and blending the powders was successfully designed and fabricated. The particle size has been reduced from 4.233 µm to 1.742 µm for 150 rpm, 4.233 µm to 1.548 µm for 200 rpm and 4.233 µm to 1.361 µm for 230 rpm for duration of 25 hours. The SEM images show the reduction of particle size from course to finer size. Ball milling had a significant effect in reducing the particle size at variable speeds.

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