DESIGN AND FABRICATION OF MINI BALL MILLING MACHINE

MEB4244 DESIGN PROJECT- II (2019-2020)

Submitted by

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BONAFIDE CERTIFICATE

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ABSTRACT

This project is to design and fabricate a mini ball mill that can grind the solid state of raw materials into fine powder. Ball mill is a cylindrical device that used to grind and blend raw materials and it rotates around a horizontal axis, partially filled with the material to be ground plus the grinding medium. When it is controlled by speed, the load nearest the wall of the cylinders will break and it quickly followed by other particle in the top curves and form a sliding stream containing several layers of balls separated by material of varying thickness. Ball milling must be operated in a closed system, with oversize material continuously being recirculated back into the mill to be reduced due to internal cascading effect. In our project, we need to fabricate a low cost mini ball mill. To fabricate this ball mill, we first design a model using Solidwork and checked for interferences. Then, we start looking for suitable material to fabricate the jar and carry out machining in lab to make some supporting parts such as shaft and metal block. After all parts are done fabricated in desired dimension, testing is carried out to determine whether the raw material selected can be grinded into powder form. Lastly, a metal bar is added inside the jar to lift up the stainless steel balls to fall from higher position so that the specimen can be crushed which is known as cascading effect.

1. Keywords: Ball mill; cascading effect; grind;

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1. INTRODUCTION

Ball mill machine is a type of grinder used to grind and blend many materials into fine powder [1,2]. It has been used to produce Nano crystal line materials [3, 4]. Until now Nano crystal line metals with a grain size from 5 to 22nm have been obtained by ball milling for fcc, bcc and hcp [5,6]. A compromise between good antiparticle or intercrystalline bonding and minimum porosity on the one hand and a minimized coarsening of the grain structure on the other has to be made. It is therefore important to investigate the thermal stability and grain growth behaviour of Nano crystalline materials [7]. It is used to grind many kinds of raw materials so the basic properties of the milling bodies are their mass and size, ware rate, influence on the particle breakage rate and energy efficiency of the grinding process [8-10]. Nearly all materials can be processed, including metals, organics and pharmaceutical, as well as composites or low-dimensional structures. Ceramic materials can be produced either indirectly or directly via ball milling [11, 12]. There are two ways of grinding: first the dry way and the second is the wet way. There is another type of ball mill machine called mini ball mill or planetary ball mill [13]. Planetary ball mill is smaller than common ball mills and mainly used in the laboratories for grinding sample material like ceramic or other raw material to a very small size or powder. Usually planetary ball mill consists at least one grinding jar and must be operated in a closed system. For the more efficient grinding there is some specific operating speed that needed. When it is controlled by

The speed, the load nearest the wall of the cylinders will break and it quickly followed by other particle in the top curves and form a sliding stream containing several layers of balls separated by material of varying thickness [14, 15]. There is some action caused by the turning of individual balls or pebbles and secondary movements having the nature of rubbing or rolling contacts occur inside the cylinder. Moreover, in this type of mill, it has been considered as high energy. It is because, the milling stock and balls come off the wall and the effective centrifugal force reaches.The figure shows principle of ball milling.

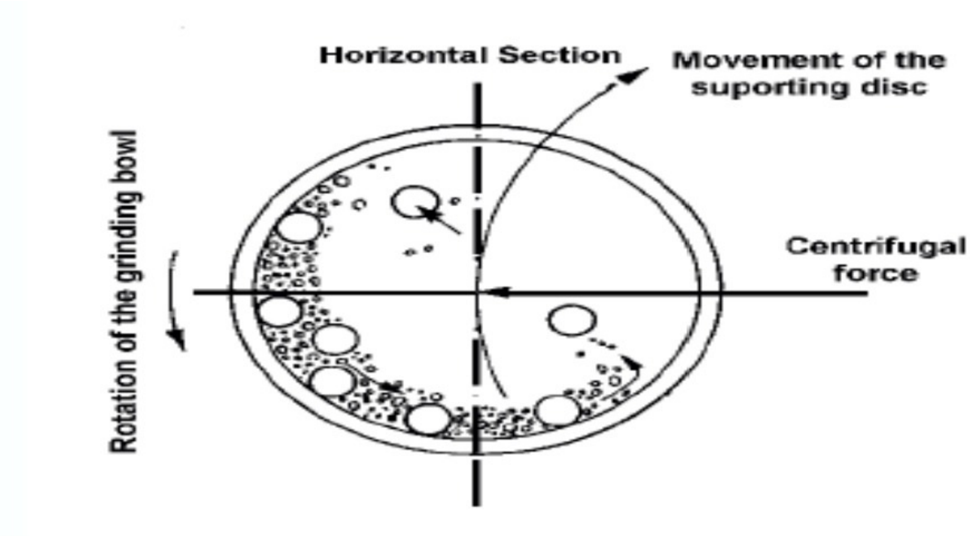


Figure 1. The working principle of ball mill.

In both rotation–revolution relationships, the specific impact energy increases with an increase in the rotation-to-revolution speed ratio in the initial stage and then falls around the critical speed ratio. The highest value in the specific impact energy of balls during milling can be achieved effectively around this critical speed [17]. Anyhow, the rate of breakage decrease as fines accumulate in the bed and applies to all sizes in mill [18, 19]. As the amount of powder is increased, the collision spaces between the balls are filled and higher rates of breakage are obtained [20]. Besides that, the maximum grinding rate shifts toward higher rotational speed range as the ball size becomes large [21]. The particle size distribution width was lowered by using larger grinding balls in dry condition [22]. The optimum milling time depends on the type of mill, size of the grinding medium, temperature of milling, ball-to-powder ratio [23-27]. The optimum ball size distribution is thus determined by the amount and combination of grinding balls of different diameters in the make-up charge [28].

Regarding the speed of the jar which cause cascading effect, when rotation speed of milling jar without lifter bar is below 75% of critical revolutions per minute (rpm), balls slide in the jar. As rotation speed of milling jar increases up to 93% and 140%, the mode of balls motion changes to cascading and cataracting type, respectively. By setting even one lifter bar in the jar, balls move as cascading mode and cataracting mode at 37% and 56% of critical rpm, respectively. As number of lifter bars increases, the necessary rotation speeds of milling jar for cascading mode and cataracting mode decreases drastically [29].

2. OBJECTIVES

In our project, we aimed to fabricate mini ball mill that can grind steel specimen into powder form. After that, we will determine the relationship between RPM, time needed and fineness of powder. Lastly, we found that by adding lifted bar inside rotating jar can help to increase workability of the whole system.

In our project,we aimed to fabricate mini ball that can rind steel specimen into powered form.

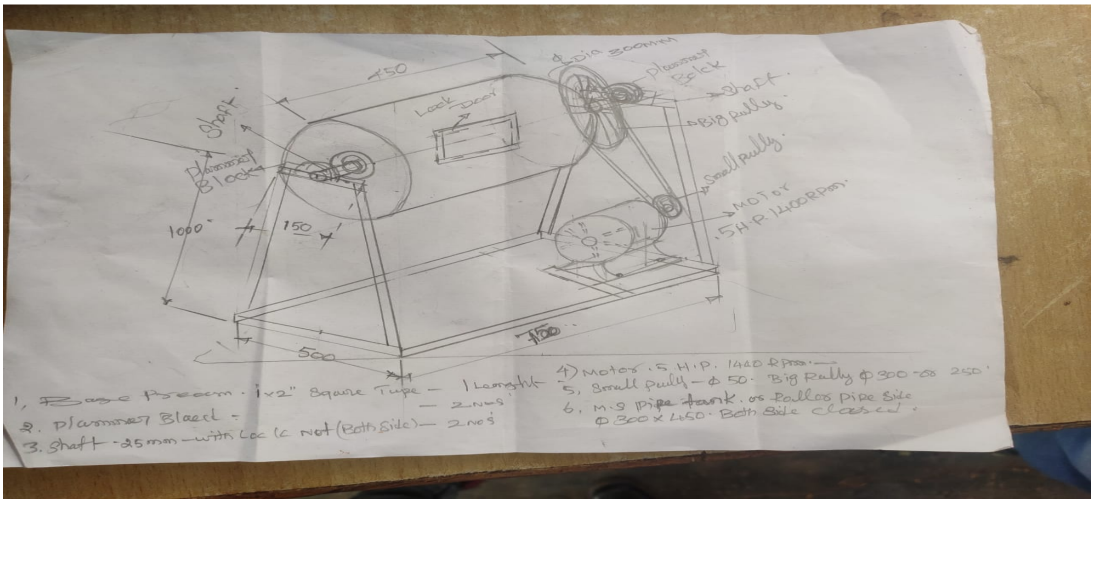
3. METHODOLOGY

The main component of ball mill is a jar with the diameter and length of a reasonable proportion. Rotated through transmission machinery, the material goes around the jar. Because of the impact of steel balls from higher position, the material can be crushed into pieces and then becomes powder if it is left longer in the jar. In mill cavity, big balls will be drive to top of the cavity by centripetal force, then they will fall to bottom of the ball mill cavity, and the balls will rap materials. Small balls will grind material at the bottom of the cavity [30, 31]. To fabricate this system, we first looked for the suitable material to fabricate the jar which have higher hardness than the raw material to be grinded. For the grinding balls to crush the raw material, stainless steel balls are the most preferable due to its hardness and the anti-corrosion property because corrosion may occur in ball milling due to high metal environment [32]. Different sizes of metal balls are used to break the material into different size portions. The commination in the ball mill takes place by impact, friction, and abrasion [33]. Since the jar is rotating all the time, there is a need for a strong stand to lift up the system. Mild steel is more preferable to fabricate the shafts and blocks since mild steel has an acceptable strength and also this material is available in store. Bearings are installed to enable rotational or linear movement for shafts, while reducing friction and handling stress. To rotate such heavy model, high power motor is required and we were able to get an old motor. The motor runs at 135W, 220-240V and 50Hz. Pulley system is used to transfer the torque from motor to the jar. At last, when the grinding is done, the grinded components and stainless steel balls will be poured on a sieve to filter the smaller components.

4. EXPERIMENTAL SETUP

For our experiment, we used AISI 304 stainless steel (70.6% Fe, 0.1% carbon, 1% Si, 2% Mn, 0.045% P, 0.15% S, 17% Cr, 8% Ni, 1.0% Cu and 0.01% N) as our grinding media and grinding jar. For the jar, the diameter of 300mma is chosen as our design. The jar has approximately 1200ml of volume and it can withstand 2kg of grinding media. For grinding media, 5mm and 10mm diameter of stainless steel balls are used. For our shafts, we used the mild steel provided in store and went to labs for machining purpose. There are two shafts in our system- main shaft and normal shaft. The head of main shaft is reduced to 16mm diameter using lathe machine to fit in the pulley which has 16mm hole at middle. For the body of shaft, we reduced it into 18mm diameter and wrap the middle part with a layer of rubber. This rubber is used to increase the friction between the shafts and jar so that the torque transmitted from motor will not be reduced much.As we prepared the materials rough sketch and no of items listed in the given project . Above shows the rough regarding project design. Number of items listing and diagram representation shown below

Figure 4.1



. Cylindrical box surface(150*300diameter)

1. **Rectangular surface(750*500 cm in lenth)**
2. **Induction motor.5HP,1450rpm**
3. **Pulley shaft(25mm)**
4. **Small pulley 50 DIA &large pulley 250 DIA mm**
5. **Plumber block……………………….**
6. **AutoCAD diagram**

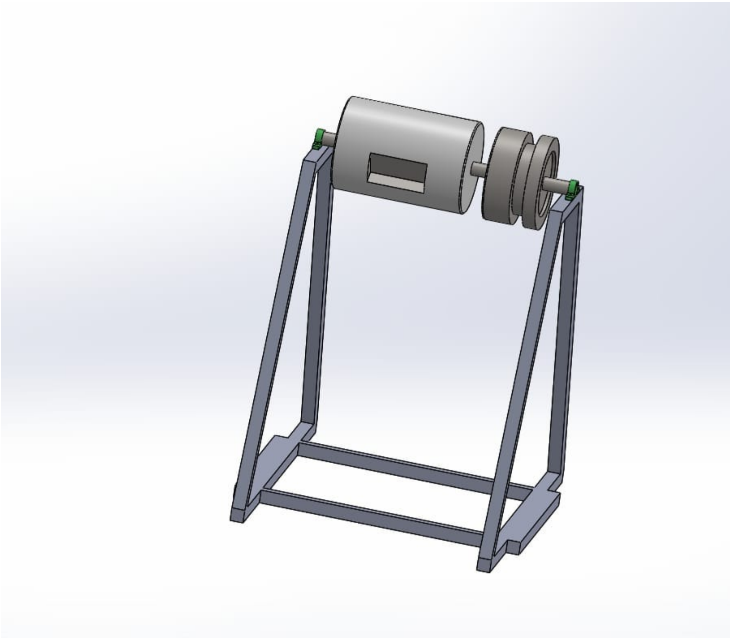
figure 4.1.1

figure 4.2

figure 4.3

Materials used in fabrication ball milling machine

Figure 4.4



3D AUTO CAD DIARAM OF BALL MILLING MACHINE

5. LITERATURE REVIEW

IRON NICKEL ALLOY

Stodart and Faraday (1820) attempted to prepare artificial meteoriciron by fusing horseshoe nails with 3 and 10wt.% Ni in an air furnace.Specimen of these alloys exists today and have been analysed and tested by Hadfield (1931).

Berthier (1827) found a meteorite which consists essentially of ironand 8.6 % Ni. Berthier suggested procedure for the artificial preparation ofsuch materials.

Harumatsu et al (1990) prepared Iron-Nickel based metal-metalloidpowders by mechanical alloying. It showed at amorphization metal- metalloidsystems (ductile to brittle systems) can be fully achieved by ball milling alonewith out performing additional treatments such as annealing using highmilling energy.

Oleszak and Matyja (1995), reported that the nanocrystalline bcc alloys of Fe-Ni and Fe-Al with a grain size of 5-15 nm are synthesized by ball milling of metal powders in a vibration mill for 300 hours.

Chronology of development of mechanical alloying(Suryanarayana 1998)

Mechanical alloying was developed around 1970 by JohnS.Benjamin and his colleagues at the Paul D. Merica Research Laboratory ofthe International Ni Company (INCO). The main goal was essentially tocombine the advantages of precipitation-hardening and oxidedispersion strengthening in a Ni-based super alloy intended for gas turbine applications. This process was referred to as "milling/mixing", but the term mechanical alloying was first coined by a patent attorney for the INCO. The recognition of the mechanical alloying as a potential non-equilibrium processing technique came after the formation of an amorphous phase by mechanical grinding of Ni-Nb system by ball milling of blended elemental powder mixtures in 1983 (Koch et al 1983).

Spassov et al (2003) investigated the optimization of the ball milling and heat treatment parameters were synthesized of amorphous and nanocrystalline Mg2 Ni based alloys. They reported that the samples containing amorphous phase after mechanical alloying (Ball Milling) formed coarser grained nanocrystalline Mg2 Ni (10-15 nm) during annealing than the alloys prepared by long time milling only (< 10 nm).

Amador and Torralba (2003) used successfully mechanical alloying to produce non-equilibrium microstructure with a high degree of homogeneity. In their work iron powder was mixed with Ni-Cu pre alloyed powders. Mechanical alloying was performed in an argon atmosphere at room temperature at different milling hours using a high energy attrition ballmilling. They concluded from the morphological study that three stages like particle deformation, cold welding and equilibrium between the two seemed to determine the particle size.

6. EXPERIMENTAL PROCEDURE

In our project, we aim to grind raw material into powder form. To carry out the experiment, we first need to make sure the motor runs at constant speed all the time. This is due to varying speed might affect our result when the experiment is done. We first need to fill in 25% of jar volume with stainless steel balls [34]. Different diameter of balls (10mm and 5mm) are used to break specimen into different sizes. For the specimen, we fill it up to 25% of the jar volume. After all the balls and specimen are inserted, we use rubber to cover the feeding part and make sure whole rubber fully closed the part. Switch on the motor and observe any part (nuts and shafts) is loosen due to the heavy vibration of the system. Tachometer or manual calculation is used to determine the RPM at the starting phase and end phase to ensure the speed of motor is not slowed down due to long duration heavy duty, thus we can obtain a constant RPM during the whole experiment. For every two hours interval, we will stop the machine for a while and observe the changes in the size of specimen. By repeating the grinding process for few more times, we will stop the experiment once the specimen has turned into powder. The time consumed is then total up and recorded. Lastly, the balls and specimen will be poured out on sieve to filter away smaller particles. The product is observed and captured.

7. FORMULA USED

It has been commonly accepted that the critical rotation speed is a function of a ball radius and a jar diameter. However, show that the critical rotation speed significantly depends on ball-containing fraction in jars, and approaches a value asymptotically as the ball-containing fraction approaches to one [35, 36]. The critical speed needed for jar is given by Eq. (1):

$$C.S = 265.45 \sqrt{I.D-d} \quad (1)$$

Where C.S is critical speed, I.D is the internal diameter of jar and d is the size of media. All the units are in inch and speed in revolution per minute (RPM). To determine the desired jar RPM, usually 55% to 75% of critical speed is required. In our experiment, we are taking 75% of the critical speed to maximize our impact energy. To determine how many balls to be put in the jar, we have to find it out using the formula below:

$$\text{Density} = MassVolume \quad (2)$$

From the specifications provided by Changsha Deco Equipment Company Limited, the density of the stainless steel balls is 7930kg/m3 each. Due to stainless steel balls have to fill up 25% of the jar volume which is 0.0012m3, we take (0.25* 7930* 0.0012) kg and we can get the mass of balls needed. Using digital scales, we can measure the mass of balls we calculated. Impact energy on each particle is crucial in our system, insufficient impact energy might cause the failure of the grinding process. To determine the energy acting on the specimens, we assume that no energy loss during the rotational motion:

$$Mgh = 1/\ 2mv2 + 1/\ 2I\boldsymbol{\omega}2 \quad (3)$$

Where m is mass of balls, v is velocity of the balls, I is the moment of inertia, is the rotational speed. After obtained the total kinetic energy of the system, we divide it by the mass of the balls to get the force per kg on the balls.

MATERIALS COST

In our project, these are the main components. There are few components we purchased from outside while some other parts we fabricate ourselves.

ITEMS	QUANTITY	COST
Stainless steel	1	300
Circular base	1	1000
Induction motor	1	2500
Steel rods basement	12	2500
Pulley, shaft, bearings	6	700
Total		7000/-

MATERIALS SPECIFICATIONS

ITEMS	DIMENSION	MATERIALS
Steel balls	10mm	AISI304 stainless steel
Pulley, shaft	50mm,250mm	Aluminium
Rectangular basement	750*500mm	steel
Circular base	450*300diameter	Steel
Ball bearings	17mm diameter	
Main shaft	25mm, 50mm	Mild steel

8. RESULT AND DISCUSSION

RESULTS AND DISCUSSION

Figure 8.1

(a) (b)

Figure 10. Experiment for the first trial (a) before grinding; (b) after grinding.

The figure above shows the difference before grinding and after grinding. We took some metal scraps in our laboratory and grinded for 2 hours. The mistake we did is not cleaning up the scraps before putting in the jar, this caused us some problems such as the steel balls are blacken with dirt and some grinded products are sticking to the wall due to the grease. These matters will be taken as precautions when we are going to carry out next trial.

In our first testing, the product obtained is not that satisfying. Only some metal scraps are turning into smaller portion even we grinded for 2 hours, the changes seem not much as we expected. Thus, we added a metal bar inside the jar to act as a lifting tool to help carrying the stainless steel balls to reach certain height and fall to crush the specimen. The result has obvious difference as shown in table.3

Table 3. Data table for experiment

Specimen	Trial	RPM	Duration	Fineness of product
Metal scraps	1	160	2 hours	 (without lifting bar)
Metal scraps	2	160	2 hours	 (with lifting bar)
Metal scraps	3	160	6 hours	

These shows difference between speed and nature of stainless steel materials with respective to their RPM.

9.CONCLUSIONS

For our objectives, we are able to achieve the first objective which is to fabricate a mini ball mill that can grind steel specimen into powder form. From our first trial, we were able to gain some product that is not ‘powder’ enough after two hours of grinding but there is a mistake made during grinding. We will improve it and continue with the next trial and achieve our second objective which is determine relationship between RPM, time needed and fineness of powder. Throughout our project, we found out that determining all the variables before fabricating is essential. By knowing the required parameter, fabricating become easier as no huge changing of design is required. Scheduling activities using Gantt chart can help to urge all members on the progress of our project as it can help to estimate the time remaining for us.

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