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Research Article

Effects of Mill Speed and Air Classifier Speed on Performance of an Industrial Ball Mill

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Abstract

The research focuses on the mill speed and an air classifier speed effect on the two compartment Cement ball mill performance in terms of Blaine, Sulphur trioxide contents, mill power, mill residue and mill residence time. Within the content of this work, sampling campaigns were organized around a cement grinding circuit and varying cement ball mill speed as well as an air classifier speed at various dosage feed rate. The fact that such an examination has not been made previously by using industrial data, which makes this work unique. The fineness is measured in terms of Blaine number. It was deduced that depending on the speed of mill and air classifier, their effects on Blaine , SO_3 , mill power and mill performance were varied, ultimately all of them improved the performance of grinding and classification operations were The Blaine quality dictates strength, setting time and overall performance of cement. Optimum performance of ball mill could potentially refine Blaine fineness, thereby improving the cement quality. This study investigates the effects of separator speed and mill speed on Blaine fineness, mill residue, consumed power. Variations in clinker feed rate, mill speed, separator speed, grinding aid could proportionally impact the grain quality of Blaine. When the separator speed is increased from 850 to 900 the Blaine is increased from 2800 to 3000 cm^2/gram and mill residue decrease from 15 to 10. Therefore, optimum parametric combination could reduce power consumption while improving the cement quality. The fact that such a study has not been carried out at an industrial scale, makes it one of its kind. Knowledge of effects of parametric variations on the quality of end product could be helpful for controlling product quality. Furthermore, proper grinding of clinker produces fine Blaine at first place and reduces the need for recycling of coarse grains.

Keywords: Clinker; Cement; Blaine; grinding process; Ball mill speed; Air Classifier speed.

Introduction

Cement Ball Mill

A ball mill is a type of grinder used to grind, blend and sometimes for mixing of materials for use in mineral dressing processes, paints, pyrotechnics, ceramics and selective laser sintering. Ball mill in the cement industry is used to reduce the size of clinker into fine particles also called as cement. Mill speed and air classifier speed were the investigated parameters for the closed cycle mill. Almost six speed level are used in the closed cycle mill are 750, 800, 830,850, 900, 950 rpm. Blaine is the important characteristic of ball mill which is influenced by the mill speed and separator speed. Ball mill is grinding equipment which is used to reduce the size of clinker into cement. It uses grinding media in the form of balls. Clinker coming from the silo is sent into hopper and mill for impact action. Clinker is introduced into the ball mill. The rotating mill is filled with different steel balls of sizes 25 mm, 40mm, 50mm, 60 mm, 70mm and 80 mm with 45%, 40% and 15% weight percentage, respectively. It is crucial to increase the efficiency of comminution process to reduce the amount of energy used and greenhouse gas emissions. First chamber consists of large size media, having diameters of the order of 80-40 mm while second chamber consists of media; having size of the order of 40-25 mm. Electric power is also affected by the media and processing parameters.

For instance, for 1000 kg cement production almost one- third power is consumed in cement mill [1]. The lab scale results could differ from the actual or industrial scale results because of different operational scale and different control of parameters. In some cases, the reduction in power consumption could be as low as half in industrial mills as compared to lab scale mills, despite using the same grinding aids. Such a change has also been reported to significantly alter the mechanical properties of cement. Using grinding aids, the decrease in power consumption in lab scale mill has been reported as 30% and 34% for glycol and amine whereas, for industrial scale, the decrease has been reported as 5% and 12% respectively. Water demand for industrial mill has been reported as 20% more as compared to the lab scale mill. In comparison of industrial and lab scale mills for 28-day compressive strength, the increase of almost 10 MPa has been reported for the industrial mill [2]. The optimization in the processing parameters could be equally useful for other mill configurations like vertical mils and high speed mills [3]. Mechanical milling method has been observed to be one of most economical and popular method for improving Blaine [4].

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Same effect has also been witnesses in case of grinding aids. Results, typically of power consumption have been over served as skewed in a lab scale ball mill, when compared to the industrial scale ball mill [5]. Likewise, the ambient conditions, climate, raw material and human factor could also impact the performance of ball mill [6].

Therefore, some type of calibration is required in the as obtained results of a lab based ball mill, before anticipating or applying those on an industrial scale. This implies that mill processing parameters could potentially affect the Blaine, emissions and residue.

This motivated the authors to investigate the effects of such processing parameters on a real-time industrial scale. The feed to the ball mill consists of clinker about 95 percent and remaining are grinding aids like gypsum, ash and ethylene glycol. Some media contains cement particles on their surface which shortens their grinding capability. Additives and powders of differential grain sizes could influence the mechanical strength of the cement [7]. The preparation of powder with typical specification and on an industrial scale could be challenging, as it demands understanding of effects of parametric variations on the powder quality. Altun et al., [8] investigated the effects of media, mill speed, feed rate and stirrer speed on the size reduction and power consumption on a customized horizontal mill.

It was observed that feed rate causes decrease in energy consumption. This is because the balls in empty mills would strike to the walls and cause increase in electric load and noise. The analysis of separator speed, residue and Blaine quality were overlooked in the study. The hold time could potentially reduce grain size as particles would be subjected to grinding for relatively longer time. Too prolong grinding times could however cause extra fineness, which leads to agglomeration. In an industrial unit, slight variation in hold could significantly affect the overall quality of cement. Therefore, wise selection of grinding time could improve Blaine and cement strength [9, 10]. Likewise, grinding time could also affect the fineness, which results in improved Blaine and cement strength. However, too fine grains could halt Blaine quality due to cause agglomeration [11]. Ghiasvand et al. [12] reported that the increase in milling time increases the Blaine for almost all types of cements. Typically, the increase in Blaine, measured in cm^2/g is twice as compared to time measured in minutes. The increased separator speed could enhance filtering capabilities of the cement,, thereby allowing finer particles to pass, which could also improve Blaine [13].

Schnatz [14] varied L/D ratio and ball charge filling ratio in a discontinuous semi-industrial ball mill to study their behavior on the specific energy consumption. It was concluded that the milling time depends and L/D ratio influence the fineness quality of cement. The study however, did not determine an optimal mill time. Some studies have compared the Blaine from the grinding product of open as well as closed mill [15]. Too much passage at the critical speed may not increase Blaine further and tends to achieve maximum value of Blaine. A further increase in the separator speed may not improve Blaine as it tends to saturate the Blaine [13].

O-Sepa separator

O-Sepa separator also called as Cage separators, air classifier or High Efficiency Separators. The material enters through the top of the separator. Material falls and is dispersed by the distribution plate.

Table 1: Grinding Conditions.

Parameters	Mill Characteristics	
Ball mill	Length, L (m)	10
	First Compartment	3
	Second Compartment	7
	Diameter(m)	
	Outside	2
	Inside	1.5
Air Classifier speed (rpm)		700-900
Ball mill speed (rpm)		14-18
Critical speed (rpm)		70-80% of mill speed
Feed (tons/h)		120-130
Clinker temperature		75-95 ºC
Cement temperature		90 -100 ºC
Cement size		80 micron mesh size screen
Blaine (Cm^2/g)		2500-3200
Mill type		Closed cycle

The separator material feed is carried out mechanically by means of suitable continuous conveyors. Fines are conveyed by air in external cyclones or directly to a bag filter. The main separating device is a cylindrical rotor. The rotor is like a cage composed of blades closely spaced. The rotor is operated by a variable speed drive. The rotor speed determines swirl in the classifying zone and therefore the cut of the separator

Methodology

The ball mill is a unit that has feeding doors at the start, and discharge door at the end and grinding mechanism in the at center. The clinker enters form the inlet door is ground in the rotating mill till the desired Blaine value is achieved. Finally, the refined Blain leaves the mill and enters the separator. Wear of grinding balls were investigated after the grinding process was completed.

Materials and Method

Cement ball mill reject sample from a industry located in Pakistan in Pezu District KPK. Study about cement was done for Ordinary Portland cement with 5% gypsum content and 95% clinker. During the sampling time, the capacity of cement mill was 120 t/h and the specific energy utilization was 30 kWh /t and the Mill balls were sphere in geometry with diameters varying from 25-80 mm. The balls were made of chrome-nickel alloy steel. The ball mill vessel was made of stainless steel to prevent corrosion. A typical mill operating conditions are mentioned in table 1.

Parametric analysis and testing methods

Air Classifier is the equipment which classifies the cement particles into different sizes. The Air Classifier rotational speed was varied from 760 to 900 rpm in seven stages. The effect of blain, mill residue and SO_3 content were studied as result of variation in separator speed. Likewise mill speed was varied from 14 to 16 rpm so study the effects on Blaine and residue. All experiments were performed on industrial scale ball mill with fly ash as grinding aid. The results were drawn based on the trend of blain quality and residue on rotational

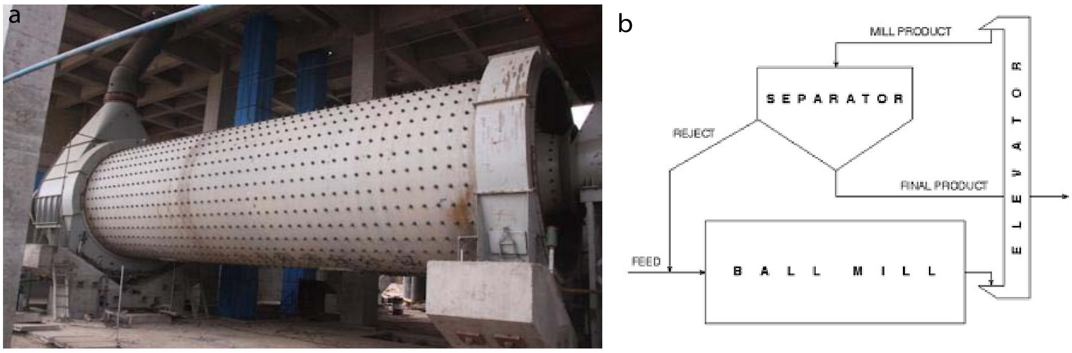


Figure 1: a) Cement ball mill view , b) Cement mill sketch.

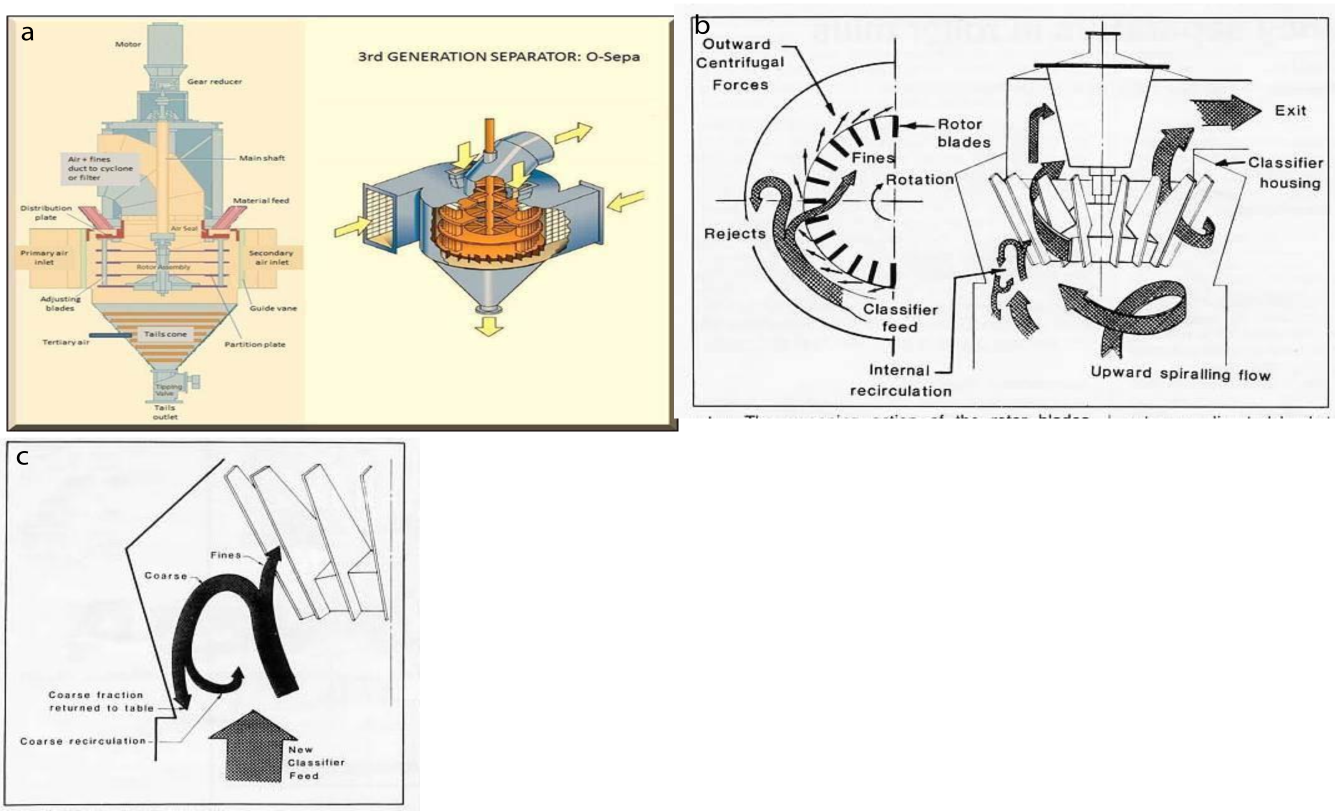


Figure 2: O-Sepa separator, sweeping action of rotor blades and recirculation scheme.

speeds of separator and ball mill [17].

Rotating speeds of air classifier and ball mills were recorded in real time from the control room of the cement manufacturing facility. Blaine size was measured according to standard blain test [18]. Mill residue was calculated through standard ASTM 80 mm mesh screen. SO_3 contents were measured through standard X-ray Fluorescence Spectrometry (XRF) method. Finally, their effects due to air classifier speed and mill rotating speed were analyzed.

Results and Discussions

Effect of Air Classifier speed on mill residue

Air Classifier is the separator which isolates coarse particles from fine particles. Mill reside is ratio of mass retained on the screen to the feed on the screen. The as separated samples were tested in the laboratory according to standard 80 mm mesh screen analysis. The increase in separator speed blocked the coarse particles and allowed fine particles to pass through. Therefore, while testing the residue using the mesh screen, the residue value decreased as the separator speed was increased. Approximately uniform decrease in residue was noticed as result of increase in the separator speed (Figure 1).

Effect of Air Classifier speed on Blaine quality

One of the most important factors to increase the throughput was the better classification. The Process due to the control speed of air classifier. As the air classifier speed increased, the coarse particles

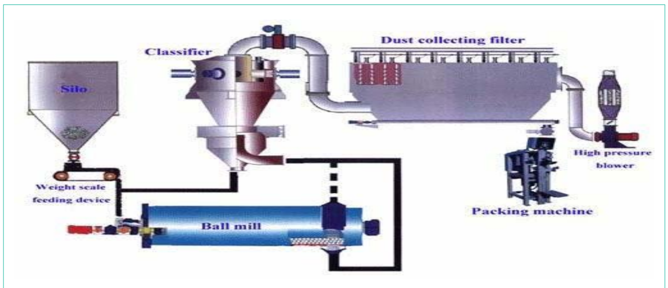


Figure 3: Ball mill.

got settled with the impact due to air classifier blades. Relatively fine particles were allowed to pass through the air classifier, thereby increasing blain quality. Comparatively high increasing trend was noticed in the Blaine quality during 815 to 850 rpm. This increase was potentially because performance of Air Classifier was higher at these rotational speeds. The Blaine has also been reported to increase due to introduction of fineness in the particle sizes [7]. The direct relation among Blaine and separator speed has also been reported in previous studies [13]. Nevertheless, surplus fineness may not significantly increase the Blaine further because of possibility of agglomeration [11]. Effect of separator stirring speed on the Blaine [16].

Effect of Air Classifier speed on Incremental increase in Blaine

Figure shows the effect of air classifier on the flow rate for incremental increase in the Blaine. It has been observed as the speed is increased the decrease in the flow rate increase the Blaine value. When the optimum speed is reached a abnormal trend is observed as can be seen from the Figure below. Speed was varied from 200, 400,600,800 and 1000 and relating to this speed flow rate changes from 500 to 1500 but with increasing trend at the start and decreasing trend at the last.

Effect of Air Classifier speed on SO_3 contents

Sulfur trioxide is the chemical compound with the formula SO_3, with a relatively narrow liquid range. In the gaseous form, this species is a significant pollutant, being the primary agent in acid rain. SO_3 contents are usually carried from the clinker duet to impurities in coal, raw material or other fuels. Proper control of SO_3 contents is through monitoring of fuel quality and raw materials composition. Introduction of limestone in cement mill may react with oxides of sulphur and produce perceptible sulfates, and thus could reduce SO_3 contents. As separator speed was increased the coarse particles, which impregnated with SO_3 contents got interrupted and were knocked down. The fine particles had already liberated any possible SO_3 contents in them and were relatively less contained with the SO_3 contents, therefore, SO_3 contents were measured relatively less (Figure 3). Loss on ignition factor due to finer grain size has also been reported in some other studies [7]. Celik et al. observed that loos on ignition increases for finer particles.

In some studies, depent on the I SO_3 contents depreciate strength of cement as well as cause environment degradation. Therefore, control of SO_3 is important parameter for strength and ecology.

An interesting trend was observed at the separator speed ranging from 815-850 rpm. All the three parameters of interest, residue, Blaine

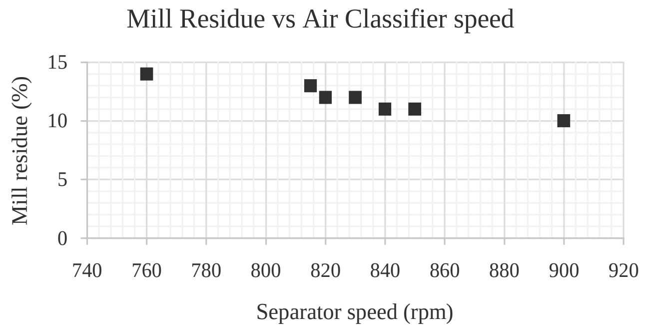


Figure 4: Effect of Air Classifier speed on mill residue.

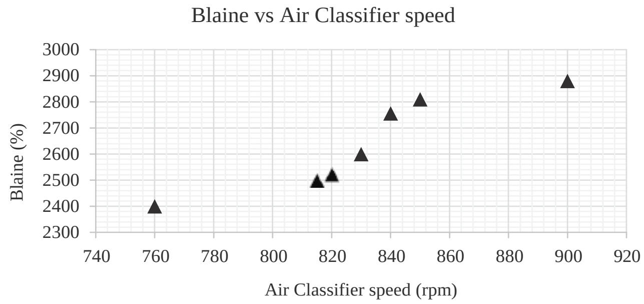


Figure 5: Effect of Air Classifier speed on Blaine.

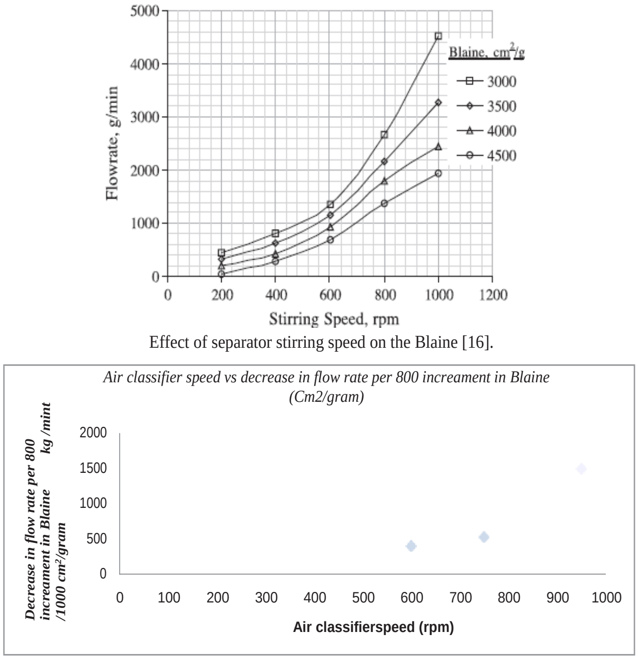


Figure 6: Effect of Air Classifier speed on Incremental increase in Blaine (Cm^2/gram).

and SO_3 were noticed to display an unusual trend in this range of Air Classifier speed. The trend however, is benign in terms of overall performance of ball mill.

Effect of separator speed on Specific energy

Figure 8 shows the effect of air classifier speed on the specific

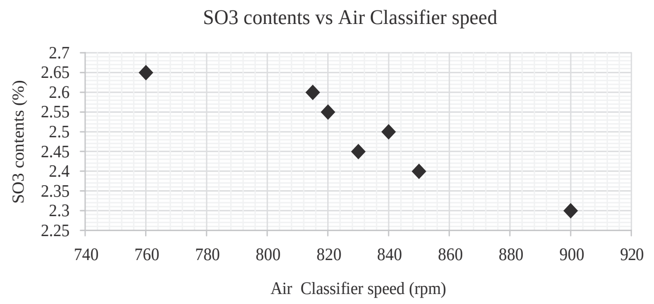


Figure 7: Effect of air classifier speed on So_3 content.

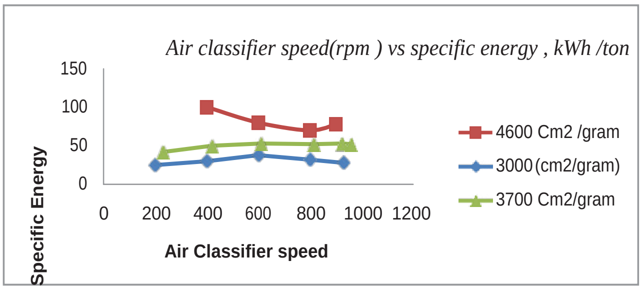


Figure 8: Effect of separator speed on the specific energy requirement.

energy requirement with different values of Blaine starting from lowest 3000 to highest 4600 Cm²/gram. It has been observed that there is increasing and decreasing trend in the graph lines. When the Blaine is 4600 cm²/gram , then specific amount of energy is decreased from 100 kWh /t to 60 kWh/t. this is the most interesting thing.

Effect of mill speed on Blaine

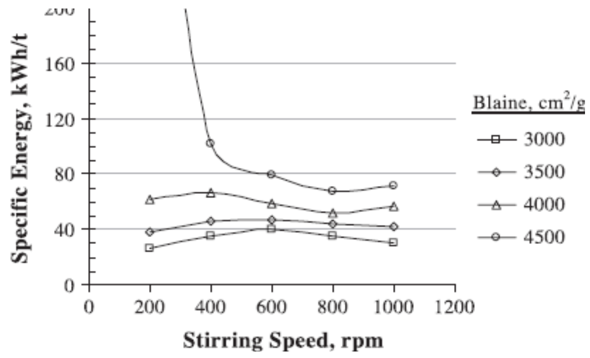
The mill speed is one of the most important parameters which governs Blaine quality. Mill rotational speed is directly related to Blaine quality, except at the critical speed, where virtually no grinding takes place as the balls are synchronized with the mill periphery. Optimum value of mill speed could potentially enhance the Blaine value. In the present study, generally Blaine quality was observed to directly relate with the mill speed. As the mill speed increased, the impact of balls on the clinker increased, which caused size reduction of clinker. At 15 rpm speed of the mill, least Blaine value was observed. This is potentially because critical mill speed is in vicinity of 15 rpm. Too high mill speed would cause irregular and non-uniform morphology in the grain [19].

Effect of mill speed on residue

Typically, residue is calculated as the ratio of oversized particles to feed on the screen. As the mill speed increases, the impact of balls increases and the size reduction is facilitated. This would in turn decrease mill residue. It could also be inferred that residue is inversely related to Blaine or fineness. 15 rpm mill speed is in vicinity of critical mill speed, thus Blaine is minimum whereas residue is higher at 16% (Figure 5). Likewise, at 14 rpm mill speed, residue is least and Blaine is relatively higher.

Effect of mill Residence time on Blaine

As the grinding time in the mill increases, the fineness of the material is increased. This is because the balls in the mill get more time to grind the clinker. Any unwanted or coarse clinker is ground to fine state in the mill. It was observed that as the clinker is subjected to grinding for relatively longer time, Blaine quality improves. The trend of increase is almost linear and proportional (Figure 6). The mill rotating speed was kept constant at 16 rpm as it produced best Blaine quality (Figure 4). The increase in Blaine is twice as compared to increase in hold time. For instance, if hold time is increased by 100 min, Blaine increased by 200 cm²/g. These effects of milling time on Blaine are in accordance with the previous studies [12,20].



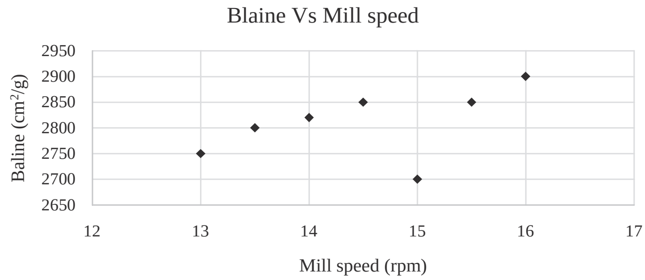


Figure 9: Effect of mill speed on Blaine.

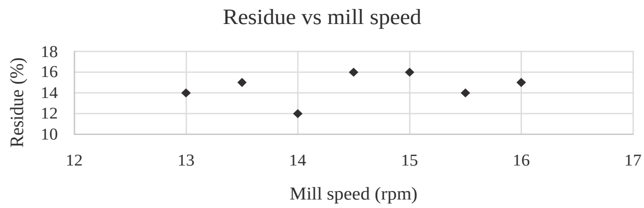


Figure 10: Effect of mill speed on residue.

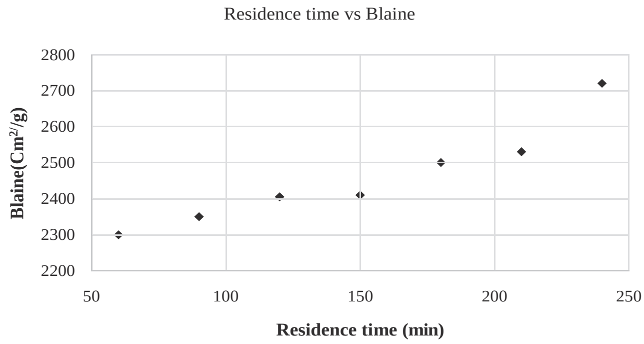


Figure 11: Effect of mill Residence time on Blaine.

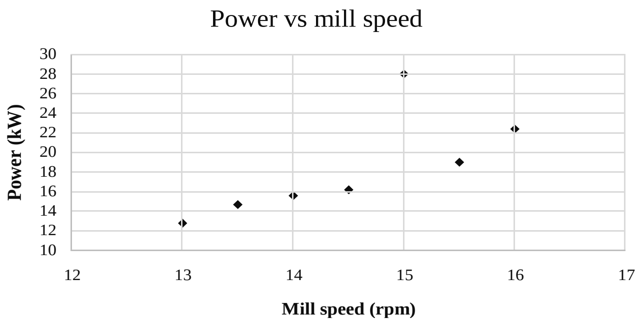


Figure 12: Effect of power on mill speed.

Effect of mill speed on power

Mill power increased proportionally with the mills speed. Figure 7 showed the trend that was relatively more noticeable at higher mill speeds as the torque demands increased to enhance grinding process. Higher mill speed could improve Blaine but also increases power consumption. At critical mill speed, power consumed was maximum and grinding was minimum. At critical speed the movement of balls is synchronized with the mill, possibly because tangential force due to mill rotation balances the weight of balls and prevents from falling down and grinding.

Conclusion

Ball mill is the major Unit operation in which the entire cost of the product relays on. But this demands huge power and media for Comminution. Media replacement with passage of time is necessary thing and critical speed is severe thing which reduces efficiency and increases power of the mill. But there is eject point from where material goes into the atmosphere. Material loss can be obviated by applying many techniques. Clinker temperature should be low for efficient mashing. Grinding aid also increase the grinding efficiency of the mill. All these should be chosen on the basis of low cost and maximum profit. Media wear and tear increases operating cost and reduces mill performance so major focus should be on this issue.

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