Applied Mechanics and Materials Vol. 625 (2014) pp 38-41
© (2014) Trans Tech Publications, Switzerland
doi:10.4028/www.scientific.net/AMM.625.38

Mechanical activation of fly ash by high energy planetary ball mill and the effects on physical and morphology properties.

Rashidah Mohamed Hamidi[1,a], Zakaria Man[2,b*] Khairun Azizi Azizli[3,c]
Lukman Ismail[4,d] and Mohd Fadhil Nuruddin [5,e]

[1,2,3,4] Department of Chemical Engineering, Universiti Teknologi PETRONAS, Bandar Seri Iskandar 31750 Tronoh, Perak, MALAYSIA
[5] Department of Civil Engineering, Universiti Teknologi PETRONAS, Bandar Seri Iskandar 31750 Tronoh, Perak, MALAYSIA

[a]shidamidi@yahoo.com, [b]zakaman@petronas.com.my, [c]khairun_azizli@petronas.com.my
[d]lukmis@petronas.com.my, [e]fadhilnuruddin@petronas.com.my

Keywords: Fly ash, Reactivity, Mechanical Activation, Planetary ball mill.

Abstract. Fly ash has a high potential to be converted into geopolymeric material due to its abundant supplies and low cost. However, large particle size of the fly ash caused low reactivity which results in low properties of the end product. The improvement on the fly ash properties by mechanical activation allows it as a new possible raw material in wider application besides solving the low reactivity issue which hindered its range of utilization. In this study, fly ash was mechanically activated by high energy planetary ball mill for 1 hour at different speed, ranging from 100 to 350 rpm and with varied ball to powder ratio (2:1, 3:1 and 4:1). The effects towards its particle size, specific surface area and morphology were determined by particle size analyzer and SEM. It was observed that, increasing of speed to 350 rpm and 4:1 ball to powder ratio (BPR) results in finest size of fly ash where at d(0.1), d(0.5) and d(0.9) the sizes were 1.861, 6.765 and 17.065μm respectively and largest surface specific area (1.46 m^2/g).

Introduction

World today is moving towards a greener technology where involvement of people in every sector and area is needed to create green inventions and products. One the efforts to pursue this is by the use of recycled and by-products material which is now no longer a demand or desire but a necessity [1]. Fly ash is one of the solid by-product of coal power plant produced from the coalescence of non-combustible material in the flue gases and typically captured by electrostatic precipitators (ESP) or a bag filter [2]. It consists of silica, alumina, iron oxide, lime, magnesia and alkali in varying amounts with some unburned activated carbon [3]. Fly ash is generated in huge amounts worldwide where for instance in China and India about 300 million tons annually. Instead of dumping it, researchers and the scientist have turned this by-product into a value added material serving in many applications mainly in construction industry [4]. Most of the fly ash is utilized as concrete or mortar addition, in road construction, as a raw material for cement, for infill voids and as geopolymers [5]. Fly ash can also be applied as raw material in other uncommon applications such as for thermal insulators or/and refractory materials and etc when subjected to some alteration via mechanical activation which results in further improvement on the properties of the fly ash itself. Moreover, the limiting factor of fly ash with average particle sizes between 10 to 30μm is its low reactivity which hindered the usage of fly ash. Mechanical activation offers the possibility to alter the reactivity without changing the overall chemistry of the material. In this work, the aim is to subject the fly ashes to mechanical activation process by using high energy planetary ball mill where the effect of speed and ball to powder ratio to fly ash properties were being studied.

Materials and Methodology

Fly ash which has been utilized throughout the study was obtained from the local power plant with particle size distribution of 2.648 for d(0.1), 14.946 d(0.5) and 139.934 d(0.9).

High energy planetary ball mill (Pulverisette), was used to carry out the mechanical activation process. Fly ash was milled in a tungsten carbide grinding jar with 10mm stainless steel balls size as the grinding medium. The milling was done for 1 hour at various speeds 100, 150, 200, 250, 300 and 350 rpm and was loaded with ball to powder ratio of 2:1, 3:1 and 4:1.

Information on particle sizes and specific surface areas of original and mechanical activated fly ash were determined by laser particle size analyser, Mastersizer S, Malvern. Images of fly ash before and after milling were displayed by Scanning Electron Microscopy (SEM).

Results and Discussion

Mechanical milling involves mechanical forces such as compressive force, shear or impact to affect particle size reduction of bulk materials. The size of the powder particle depends on several factors such as milling speed, type of milling equipment, size of balls used and ball to powder weight ratio (BPR). Table 1 shows that by increasing speed to 350 rpm and ball to powder ratio (4:1) yielded the smallest size of fly ash.

Table 1: Particle sizes of mechanical activated fly ash at varied BPR and speed

Ball to powder ratio (BPR)	Speed (rpm)	Particle Size (μm)		
		d(0.1)	d(0.5)	d(0.9)
2:1	100	2.547	13.656	78.746
	150	2.565	13.941	88.437
	200	2.573	13.543	58.449
	250	2.602	13.41	52.94
	300	2.471	11.809	37. 936
	350	2.514	12.215	42.289
3:1	100	2.504	13.514	73.226
	150	2.523	13.278	63.318
	200	2.434	12.147	39.642
	250	2.274	10.836	29.987
	300	2.148	9.555	23.957
	350	1.861	9.957	25.014
4:1	100	2.504	12.976	66.91
	150	2.523	12.76	56.029
	200	2.435	11.489	37.798
	250	2.274	9.436	23.395
	300	2.148	8.504	20.358
	350	1.861	6.765	17.065

Higher speed contributes to high velocity of the balls movement in the grinding jar hence more shearing action or impact occurred. However, some results obtained contradict to the stated theory where increase in speed gave a bigger particle size which may due to the agglomeration of the fine fly ash during the particle size analysis. High BPR indicates that more balls are present in the grinding jar compared to the feed stock (fly ash) which allows more effective collision between them and more particles were being crushed. Figure 1 illustrates significant fly ash particle size reduction after mechanically activated at the highest speed (350 rpm) and BPR (4:1) compared to the original fly ash. Particle size of fly ash at d(0.1), d(0.5) and d(0.9) were 2.648, 14.946 and 139.934μm initially and went down to 1.861, 6.765 and 17.065 μm respectively.

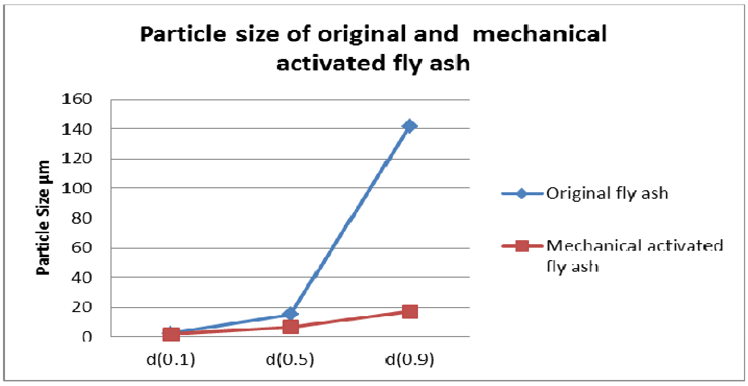


Figure 1: Particle size of original and mechanical activated fly ash.

Based on the results obtained, mechanical activation indeed proved to be a good tool in overcoming the limitation of original fly ash properties which is the low reactivity. Figure 2 demonstrates the increasing of specific surface area of the grounded fly ash (GFA) which is 1.46 m^2/g compared to 0.893 m^2/g of the original fly ash (OFA). Fact has it that the finer the particle size the larger the specific surface area and hence reactivity of the particles will be greatly improved. Mechanical activation able to enhance the properties of fly ash and allows it to be utilized in wider application.

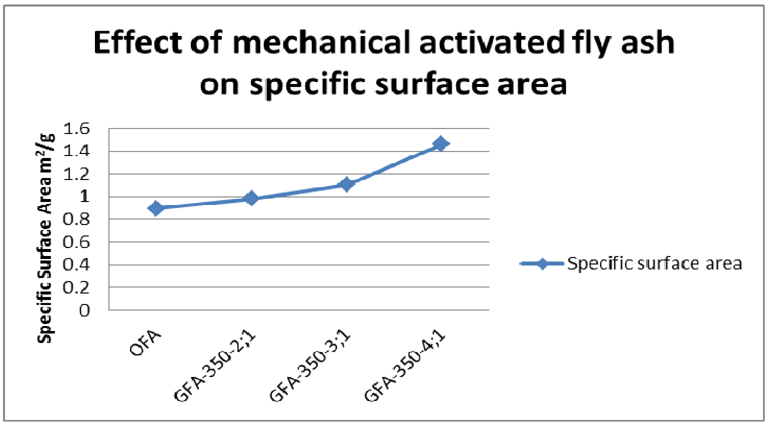
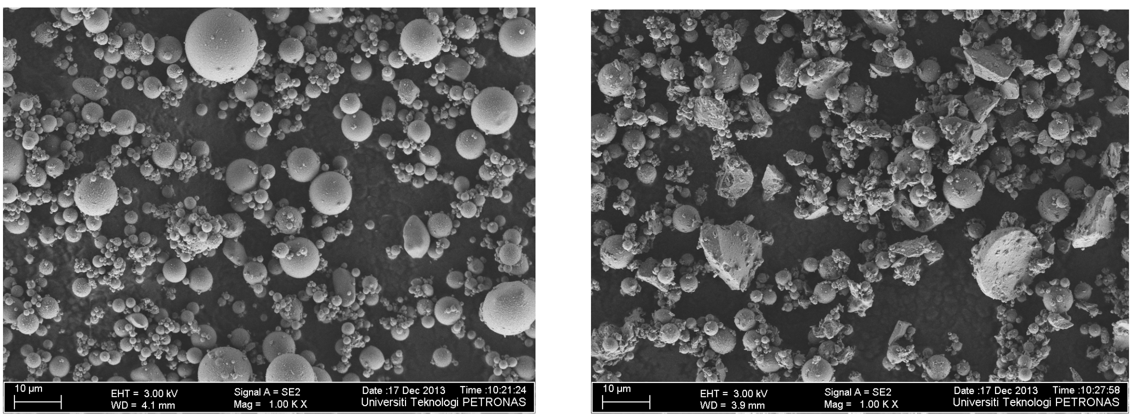


Figure 2: Specific surface area

All particles loaded in the grinding jar will have the possibilities to be crushed, but only some of it undergoes the crushing process during milling and others will remain the same size as they were initially. This phenomenon is due to the crushing process during mechanical activation is random and it has been proved by the images shown in Figure 3 where some fly ash particles were crushed and some were not.



(a) (b)

Figure 3: FESEM images of (a) original and (b) grounded fly ash

Conclusion

The results obtained shows that, mechanical activation using high energy planetary ball mill yielded in significant particle size reduction at the highest speed and BPR which were at 350 rpm and ratio of 4:1 respectively. This had improved as well the specific surface area of fly ash which will improve the reactivity and consequently give better effect towards the properties of future end products.

Acknowledgment

The authors gratefully acknowledge the Ministry of Higher Education (MOHE) for funding the research work under Long Term Research Grant Scheme (LRGS) and Universiti Teknologi PETRONAS (UTP) for supporting this study.

References

[1] A. Abdulhameed Umar and B. Khairul Salleh, Potential use of Malaysian thermal power plants coal bottom ash in construction, Int. J. of Sust. Const. Eng. & Tech. 3, (2012), 25-37.

[2] P. William Ross and A. Van Riessen, Determination of the reactive component of fly ashes for geopolymer production using XRF and XRD, Fuel. 89, (2010), 3683-3692.

[3] S. Anita, K. Srivasta, V. Devra and A. Rani, Modification in properties of fly ash through mechanical and chemical activation, Am. Chem. Sci. J. 2(4), (2012), 177-187.

[4] G. Mucsi and B. Csöke, Power plant fly ash as valuable raw material, Geosci and Eng. 1 (2012), 223-236.

[5]. A. Terzić, Lj. Pavlović, N. Obradović, V. Pavlović, J. Stojanović, Lj. Miličić, Z. Radojević and M.M. Ristić, Synthesis and sintering of high temperature composites based on mechanically activated fly ash, Sci. Sinter, 44 (2012), 135-146.