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Clinker grinding test in a laboratory ball mill using clinker burning with pet-coke and coal

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Abstract:- About one-third of energy required to produce one ton of cement is consumed in grinding. There are many factors affecting the energy consumption during clinker grinding. The energy consumption in the cement mills varies between 30 to 50 kWh/ton. Clinker grinding test was conducted in a laboratory mill, 500 mm x 500 mm, for a time of 5 min and the amount of 3.5 kg of clinker. The experiment was done for clinker obtained by firing pet-coke as fuel and clinker obtained by firing coal as fuel. Experimental mill is filled with different size balls. The goal of this paper was studying the grindability of clinker and its effects in ball mill efficiency. It is taken in consideration that clinker obtained by firing pet-coke has different grindability, different throughput rates, fineness data and other quality parameters. Initially, we studied the chemical and mineralogical composition of samples, and noticed changes in the results obtained. Also it is studied the residue of the samples, specific surface, where the results indicate that clinker produced by firing coal has the highest scoring of grindability.

Keywords:- clinker, pet-coke, ball mill, grindability, fineness

I. INTRODUCTION

Out of 110 to 130 kWh/ton of electrical power consumed in making cement, between 30 and 50 kWh/ton are consumed by finish milling operation (Bhatty & Miller & Kostmaka, 2004). There are many factors affecting the grindability of clinker, thus effecting the energy consumption. It is also discussed in energy consumptions and ball mill operation. Normally, the hardest clinkers require more power for grinding. Furthermore, different fineness requires different energy consumption. Clinker grindability is the measure of the ability of a clinker to resist grinding forces (Touil & Belaadi & Frances, 2003). Grindability of clinker increases with decreasing silica ratio and with increasing alumina (Al_2O_3) and iron oxide (Fe_2O_3) contents (Duda, 1985). A high content of tricalcium silicate (C_3S), results in increasing clinker grindability and the opposite happened when clinker has a high content of dicalcium silicate (C_2S) (Duda, 1985). The more liquid phase, the lower is grindability of clinker (Duda, 1985). Grandability is also effected by C_3A, C_4AF and MgO, which results in energy saving. Also, clinker containing high free lime, it is found to have higher grindability. This articles attempts to show the grindability of clinker produced by firing pet-coke and clinker produced by firing coal to the rotary kiln. For this purpose, are taken samples of clinker sintered firing petcoke and clinker sintered firing coal. When using pet-coke, it is noted that clinker has a lower granulometry. This is reason of high SO_3 content, effecting the tension surface. It’s seemed from experience that the use of small percentage of petcoke does not show these problems. The content of SO_3 in clinker increase when using pet-coke, according to the quantity of pet-coke used. Petroleum coke different from coal has non-hygroscopic nature. Humidity is usually about 8-10%, but for a better ignition in the kiln is recommended around 1-2 %. It has lower ash content than coal. Ash content is 0.3 - 0.5% and sulfur content is 5.7%. Petroleum coke is a fuel with high calorific value. Gross calorific value is approximately 8000 kcal/kg. The content of sulfur in petroleum coke depends on the sulfur content in crude oil. Pet-coke is generally more finely than coal, so there is no need for a pre grinding before storing and sending to the mill. Hardgrove grindability index (HGI), of coke and lignite are roughly the same, although coke requires more energy to grind, it's because of low fines required. Petroleum coke, which is used as fuel has a HGI between 40 to 55, where, HGI 30 refers to fuels very strong, and HGI 70 refers to fuel very soft.

II. MATERIAL AND METHOD

The laboratory ball mill used in the experiments was 500 mm in diameter and 500 mm in length. This mill was driven by variable speed drive 1.5 kW motor, voltage of applied power supply was 380 V and frequency of applied power supply 50 Hz. The ball loading weight was 100 kg. The feed charge was held constant at 3.5 kg, for all experiments and the mill was rotated at 48 rpm. For effective size reduction there should be an appropriate ratio between the size of the feed material particles and the mass of the individual grinding media (Labahn/Kohlhass, 1983). The significant effect of ball size on the grinding efficiency has been mentioned in the literature (Gupta, Zouit and Hodouin, 1985; Austin, Shoji and Luckie, 1976). The quantity of ball and forging used in the mill is described in table 1.

Table 1. Quantity of ball and forging

Steel	Ball ϕ (mm)	Quantity (piece)	W_t (kg)
Ball	70	9	60
	60	24	
	50	37	
	40	43	
Steel forge	20x30 ϕ L (mm)	374	40

All the samples were ground for the same time (5 min), and physical test are taken like:

- Residue in sieve 25µm, 45µm and 90 µm
- Specific surface (Blaine)
- compressive strength for 2 days, 28 days and 3 months

To obtain the residue and the Blaine of the samples, each sample was ground in dry conditions using same ball charge and time. The particle size distributions of the samples were determined by dry sieving technique. It was observed that the power input to the mill slightly decreased when the material becomes very fine. The chemical compositions of clinkers used in this study are listed in table 2 and 3.

Table 2. Chemical and mineralogical compositions of the clinkers produced by firing coal

	Chemical composition (%)											Mineralogical compound composition (%)				
Clinker no.	SiO_2	Al_2O_3	Fe_2O_3	CaO	Fl	MgO	SO_3	LOI	LW	LSF	SM	AM	C_3S	C_2S	C_3A	C_4AF	LP
1	21.17	5.76	3.52	65.52	1.47	1.83	0.91	0.52	1209	95.84	2.28	1.64	62.07	13.92	9.31	10.71	27.83
2	21.15	5.94	3.64	65.85	1.73	1.77	0.95	0.47	1159	96.00	2.21	1.63	62.18	13.77	9.58	11.08	28.58
3	20.77	6.14	3.64	65.62	1.71	1.85	1.15	0.48	1208	96.83	2.12	1.69	62.79	12.22	10.11	11.08	29.26
4	20.75	5.96	3.68	66.02	1.46	1.94	0.95	0.36	1221	97.77	2.15	1.62	65.72	9.95	9.57	11.20	28.90
5	20.47	5.99	3.72	66.19	1.40	1.77	0.98	0.55	1250	99.08	2.11	1.61	68.29	7.22	9.58	11.32	28.91
6	20.77	5.94	3.76	65.62	1.53	1.81	1.06	0.32	1199	97.06	2.14	1.58	63.96	11.34	9.38	11.44	28.89
7	20.54	5.88	3.70	65.91	0.97	1.85	1.20	0.36	1200	98.59	2.14	1.59	67.38	8.10	9.32	11.26	28.62
8	20.51	5.95	3.74	65.05	0.88	1.73	0.95	0.28	1273	97.26	2.12	1.59	63.58	10.88	9.44	11.38	28.80
9	20.86	5.93	3.68	65.05	1.27	1.80	1.08	0.35	1298	95.95	2.17	1.61	61.14	13.73	9.49	11.20	28.67
10	20.60	5.90	3.70	66.08	1.82	1.81	0.99	0.37	1234	98.56	2.15	1.59	67.48	8.20	9.37	11.26	28.64

Table 3. Chemical and mineralogical compositions of the clinkers produced by firing pet-coke

	Chemical composition (%)											Mineralogical compound composition (%)				
Clinker no.	SiO_2	Al_2O_3	Fe_2O_3	CaO	Fl	MgO	SO_3	LOI	LW	LSF	SM	AM	C_3S	C_2S	C_3A	C_4AF	LP
1	21.28	5.94	3.71	64.47	2.67	1.82	0.92	0.24	1155	93.43	2.21	1.60	55.5	19.20	9.46	11.29	28.79
2	21.06	5.87	3.71	64.66	2.01	1.82	1.01	0.33	1184	94.66	2.20	1.58	58.4	16.37	9.28	11.29	28.58
3	21.20	5.66	3.59	64.61	1.93	1.78	0.98	0.27	1173	94.50	2.29	1.58	58.7	16.54	8.92	10.92	27.64
4	21.35	5.71	3.71	64.66	2.09	1.78	0.86	0.40	1175	93.81	2.27	1.54	57.3	18.06	8.85	11.29	28.06
5	21.10	5.79	3.99	64.45	1.62	1.73	1.11	0.18	1188	94.08	2.16	1.45	57.4	17.26	8.59	12.14	28.88
6	21.74	5.56	4.01	64.49	1.21	1.74	1.02	0.27	1232	92.08	2.27	1.39	54.2	21.49	7.95	12.20	28.24
7	21.18	5.65	3.92	64.45	1.76	1.77	1.03	0.16	1208	94.06	2.21	1.44	57.8	17.16	8.34	11.93	28.34
8	21.33	5.77	3.98	64.73	1.57	1.61	1.20	0.27	1197	93.65	2.19	1.45	56.9	18.26	8.56	12.11	28.68
9	21.43	5.77	4.04	64.45	0.91	1.69	1.04	0.23	1229	92.82	2.18	1.43	54.9	20.05	8.45	12.29	28.89
10	21.39	5.59	4.02	64.28	1.51	1.73	1.03	0.17	1226	93.02	2.23	1.39	55.8	19.29	8.01	12.23	28.35

By comparing the results of clinker chemical compounds, we note that some of tricalcium silicate in clinker produced by firing coal is considerably higher than the clinker produced by firing pet-coke. While, in the clinker produced by pet-coke noticed that the amount of dicalcium silicate is higher. Since, alkalis are not sufficient to combine with excess sulfur, located in pet-coke, a portion of the excess sulfur permeate inside dicalcium silicate (C_2S), which can absorb up to 2% SO_3. C_2S, which has combined SO_3 in the crystal structure, has fewer tendencies to act with CaO to form tricalcium silicate. This brings an increased amount of C_2S and a lower amount of C_3S, at the final clinker. Because, C_2S is one of the most difficult minerals to grind and as its amount increases in clinker, will have a reduction of clinker grindability of clinker produced firing petroleum coke. Another reason, as a result of high SO_3 is that surface tension affects the viscosity of the liquid phase, which affects clinker granulometry. These conditions will produce a finer clinker and more dust. Production of excessive dust, adversely affects grindability of clinker. There are also indirect causes, associated with the formation of condensed material, frequent blockages and increasing free lime, which can lead operator to produce an over burned clinker.

III. RESULTS AND DISCUSSION

The experiment was conducted in a laboratory mill for two different types of clinker. For each clinker were analyzed 10 samples, where we determined residue in sieves 25 µm, 45 µm and 90 µm; specific surface (Blaine); compressive strength 2-day, 28-day and 3 months. The results obtained are shown in graphics, where you see the difference between clinker produced by firing Pet-coke and clinker produced by firing coal.

Figure 1 Comparison between coal and pet-coke residues for 25 µm

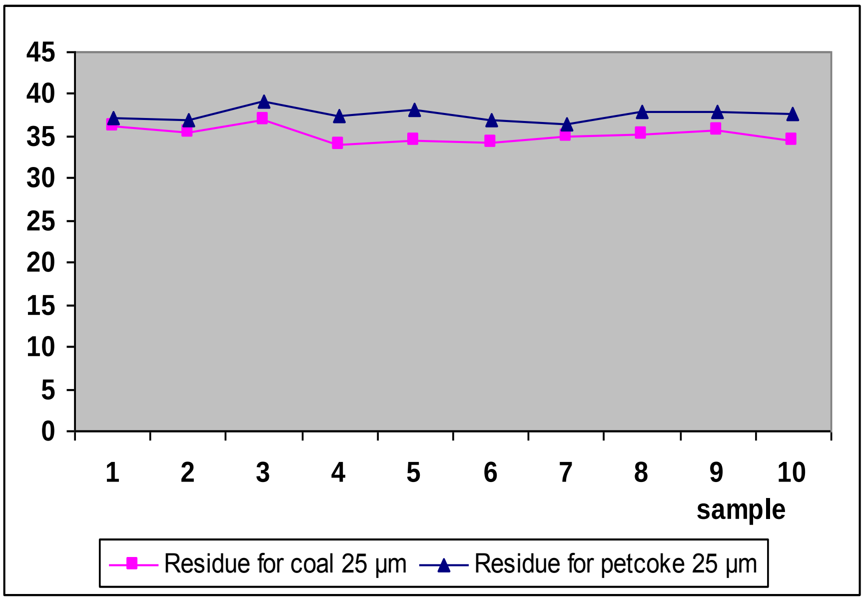


Figure 2 Comparison between coal and pet-coke clinker residues for 45 µm

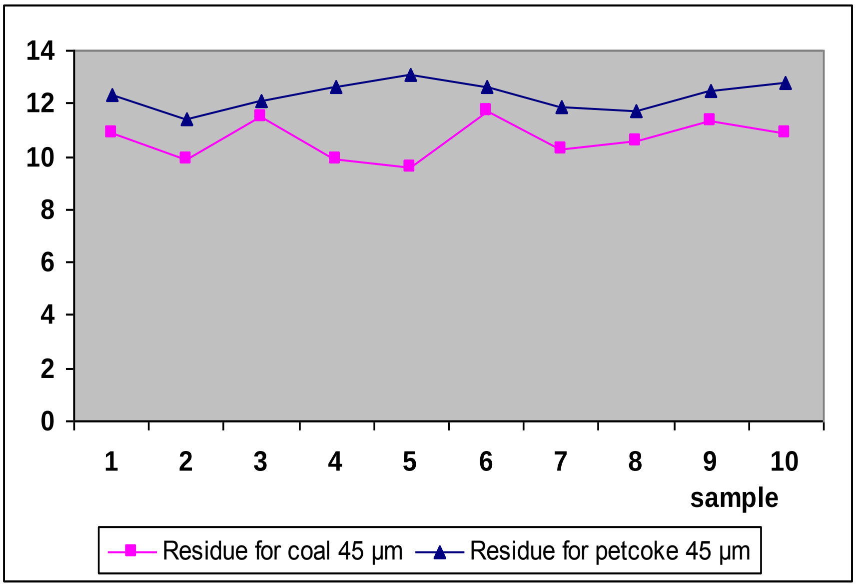
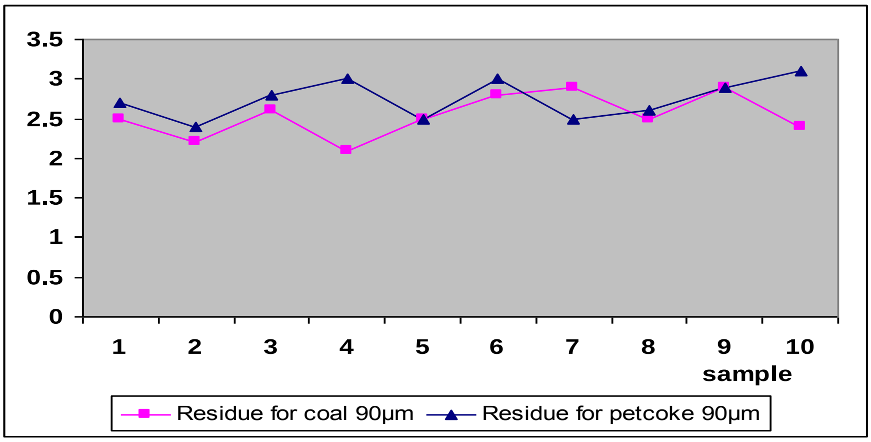


Figure 3 Comparison between coal and pet-coke clinker residues for 90 µm



In Figure 1, 2 and 3 are presented the results of residue obtained from grinding the samples. It is seen that for the same time of grinding (5 min), clinker produced by firing coal reaches a finer residue nearly for all samples of the analysis. This is a result of higher content of C_3S, therefore alite is grinding easer than belite. In Figure 4, shows the results of specific surface for clinker produced with coal and pet-coke, where it is seen that clinker produced by firing coal reach higher values.

Figure 4. Comparison between specific surface of coal and pet-coke clinker

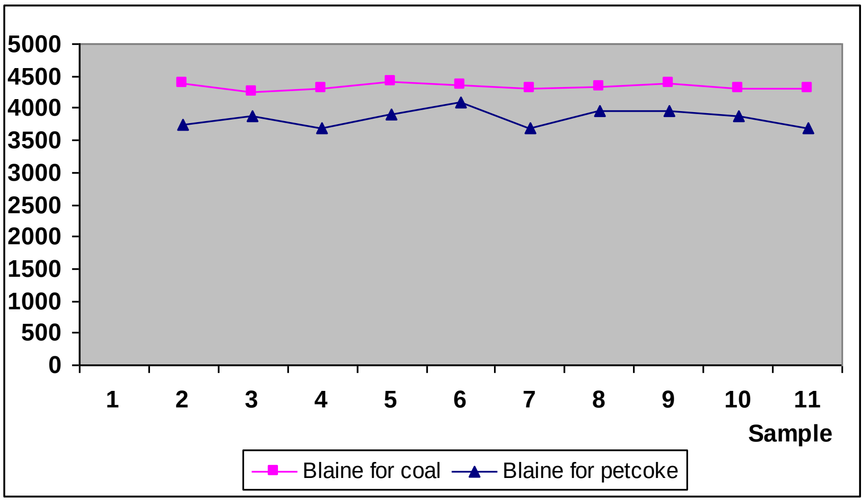


Figure 5. Comparison between 2 days compressive strength of coal and pet-coke clinker

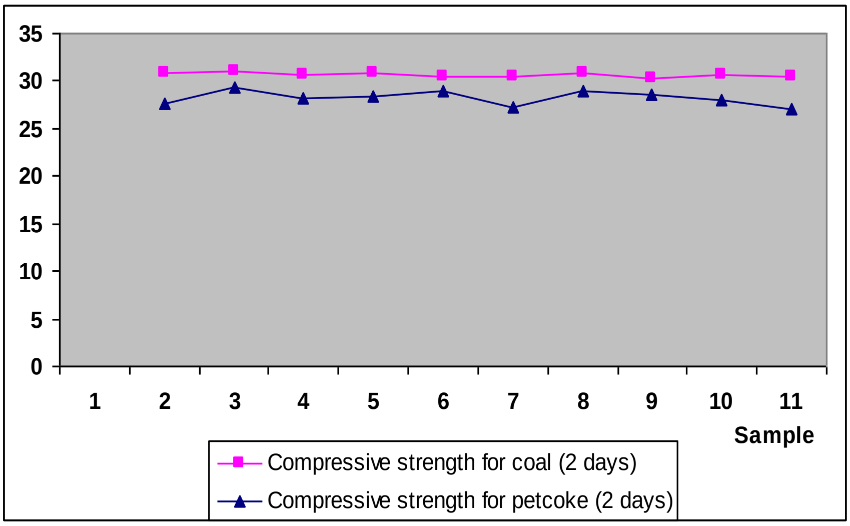


Figure 6. Comparison between 28 days compressive strength of coal and pet-coke clinker

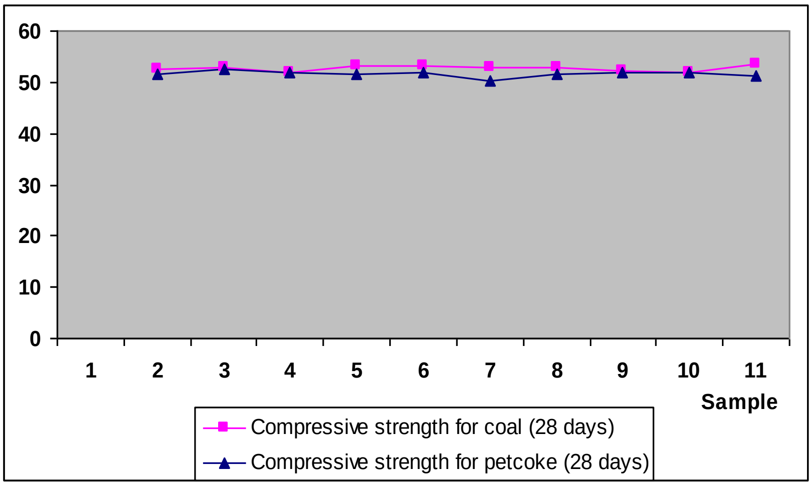
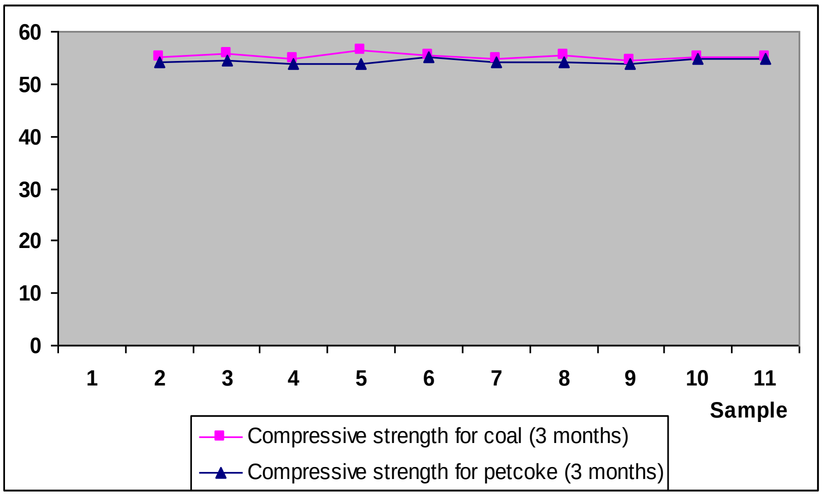


Figure 7. Comparison between 3 months compressive strength of coal and pet-coke clinker



In Figures 5, 6 and 7 are shown the values of compressive strength for 2 days, 28 days and 3 months. The results achieved indicate that compressive strength for 2 days of clinker produced firing coal is considerably higher than clinker produced firing pet-coke. This because lower residue and a higher specific surface that reaches the clinker produced by coal during grinding. Results for 28-day and 3 months indicate slightly a higher difference between the two clinkers

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