Study On Use Of Non-Magnetic Fraction Of Pulverized Coal Fly-Ash As Filler In Specialty Paper Manufacturing

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ABSTRACT

Pulverized coal fly-ash has been evaluated as wet-end filler in manufacture of specialty products such as decorative laminate-grade base papers. Fine sized fly-ash is available abundantly as solid waste from coal based thermal power plants. Non-magnetic fly ash particles smaller than 35 µm (average particle size of 19 µm) were used as wet end filler. Mechanical, optical, and surface properties of paper hand sheets were studied for different percentages of fillers. It was found that fly ash could prove to be a good filler for laminate grade colored base papers where very high opacity was sought but whiteness was not important. It will decrease the production cost of paper significantly. Utilization of fly ash will help in finding a new area of its use and provide new cheaper filler for pulp and paper industries. This will not only reduce the disposal and environmental problems but also give value to fly ash.

KEYWORDS: Fly ash, Filler, Specialty Paper, Opacity

Introduction

Sustainability of industrial growth depends on effective and environment friendly use of industrial waste materials. On one side we are facing problems of solid waste handling due to not finding suitable utilization where as on another side mining and other mineral exploration processes are putting a lot of pressure on natural resources of planet earth. Fly ash obtained from the burning of pulverized coal is very fine in particle size. A large amount of fly ash is dumped in the near by places of power plants causing environmental pollution by mixing with air, water and soil of several hectares of land. The principal contents of fly ash are normally silica, alumina, and iron oxide. These oxides are having suitable quality for being used as filler in paper.

Literature Review:

Fly ash generation in India has increased to nearly 130 million tones on annual basis during the year 2006-07 out of which only 60 million tones are being utilized as per Fly ash utilization program (FAUP) report (1). Fly ash contains nearly 35-70 % SiO_2, 15-30% Al_2O_3, 1-10 % MgO, 1-10% CaO, 5-10% Fe_2O_3 and 1-2% TiO_2 depending on the use of various types of coal and burning process conditions. Only a small quantity of the total fly ash generated from the thermal power plants is utilized in brick making, concrete, soil stabilization treatment, cement industry and other applications. Scott (2) has pointed out that the common paper making fillers are kaolin clay (typical composition of 39% Al_2O_3, 46% SiO_2, and 13% H_2O), calcium carbonate (98 -100% $CaCO_3$), titanium dioxide (98 -100% TiO_2), hydrated silica (consists of 78% SiO_2, 5% CaO, and 17% H_2O), aluminum tri-hydrate (65% Al_2O_3 and 34% H_2O), and talc (magnesium silicate). Clay is still one of the most used filler materials in paper making. Fly ash has the constituents similar to that of the commercial fillers used in pulp and paper industries. Kumar et al. (3) imply that high ash content (30-50%) of Indian coals is contributing to large volumes of fly ash. Nearly 73% of India's total installed power generation capacity is based on thermal power plants, out of which 90 percent is using coal as fuel. Giere et al. (4) imply that the total amount of fly ash produced in U.S. through coal combustion is approximately 57 million ton per year. Affolter et al.(5), Bayat (6), Nathan et al. (7), Wigley and Williamson (8), Moreno et al. (9) have mentioned chemical and physical properties of fly ash taken from coal fired power plants. These properties can be found comparable with oxides used as filler in paper industries. Sinha (10) has published the earlier study of use of pulverized coal ash as wet end filler in TAPPI Journal . Sarkar et al. (11) imply that the particle size range of the resulting fly ash is 0.2-90 micro meters for high combustion efficiency super thermal power plants. Kinoshita et al. (12) imply that the addition of filler affects the pore structure. Its interaction with paper properties is found to be important. The particle content in the sheet must be high to produce effective filler-paper interaction.

Huang et al. (13) has highlighted that the paper based laminates; melamine film, paper foil and high pressure laminate are widely used for the surface finishing of particle board and other substrates. From a global point of view, the development of the laminate's market is positive in absolute terms as well as versus non-paper-based surface materials. Demand for laminated furniture will further increase, as well as other applications of laminated board in the building industry. Rump et al. (14) imply that the porosity of a laminate paper has a strong influence on the impregnation process. Hutchins (15) says that the Decor paper based surfaces continue to enjoy over-proportional market growth versus other surface materials. Merging markets with their industrialization require more materials and open opportunities for more diverse product solutions. Krull (16) says that the environment friendly manufacturing and cost reduction are

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the main focus for sustainability of any industry. This theme was highlighted by Michel Fortin (Conference Chair person) in the TAPPI Decorative & Industrial Laminates (DIL) Symposium, August 18- 20, 2008 in Atlanta, Georgia, USA.

Experimental:

Materials:

Bleached rice straw pulp and long fiber southern pine pulp were used in the ratio of 80:20 for paper sheet making. The rice straw pulp was manufactured in paper technology laboratory using H_2SO_4 catalyzed acetic acid pulping. Sinha (17) has done the study of optimum condition and benefits of catalyzed acetic acid pulping of rice straw. The pulp was bleached to average quality by C E H P bleaching sequence. The long fiber southern pine pulp was obtained from near by paper industry. The rice straw and pine pulp were having brightness of 72.2% and 89% ISO respectively. Coal fly ash samples were collected from thermal power plant, Bathinda, Punjab (India). Kaolin clay of commercial grade was used in paper making for comparison purpose.

Fly ash Processing:

Fly ash was fractionated into magnetic and non-magnetic fractions using permanent magnets. The non magnetic fraction of fly ash was processed in ball mill for 1hr for grinding. The ground fly ash was sieved for 30 minutes in a sieve shaker using sieves no. 36, 60, 85, 150, 300, and 400 (B S 410 1986). The finest fraction, passing through 400 mesh no. (Screen opening size of 38 micro meter) and having average particle size of nineteen micrometers was used as filler in paper making.

Paper hand sheet preparation:

Dilute slurry (1% solid) of kaolin clay as well as fly ash (non magnetic fraction) was prepared for better mixing in pulp slurry. Preparation of paper hand-sheets were done by taking 200 grams of O.D. Pulp. The pulp was treated in disintegrator and then diluted to 2% consistency for beating in lab valley beater up to 40 ^{0}SR. Fillers were added in pulp slurry in 0, 10, 20, 30 and 40 wt% ratio based on oven dry pulp amount. The pulp slurry was diluted to 0.8 % consistency and then paper hand sheets of 100 GSM were made on lab sheet former with different wt percentages of fillers. The wet papers were pressed in lab sheet press and then air dried for 24 hrs. The air dried papers were sealed in polythene bags for analysis of important properties.

Testing of paper (hand sheet) samples:

The paper hand sheet samples were placed in an environmental chamber for three hours which was maintained at a temperature of 25 ^{0}C and 52% relative humidity. Important properties like brightness (ISO), opacity (ISO), burst strength, tear strength, tensile strength, Gurley porosity, Bendtsen roughness were measured as per TAPPI test Methods.

Experimental design:

Experiments were planned to obtain nearly 0%, 5%, 10%, 15%, and 20% ash levels in the paper hand sheets. The following experiments were conducted:

1. Five hand sheets of 100 g/m^2 were prepared without adding any filler
2. Kaolin clay was added in pulp slurry to make its weight percentages on oven dry basis as 10, 20, 30 and 40 in pulp slurry. Five hand sheets of each clay percentage were made on semi automated lab Sheet former.
3. Similarly fly ash was also added in different percentages on trial basis so that the retained fly ash percentage is same as that of kaolin clay. The samples of hand sheets (five for each composition) loaded with fly ash were made and stored.

Results And Discussion:

1. The filler addition improves opacity and smoothness of paper. The addition of filler as an inert material has adverse effect on most of the mechanical strength properties by directly interfering with inter-fiber bonding. Particle size and shape play key roles in determining the severity of this effect for a given pigment.
2. Addition of fly ash causes lower decrease in mechanical strength properties due to larger particle size and irregular shapes in comparison to kaolin clay. The major constituents are silica (SiO_2) and alumina (Al_2O_3) for fly ash as well as for kaolin clay. But fly ash has other oxides like titanium dioxide, magnesium dioxide, calcium oxide and iron oxide, which provide higher opacity. Lower brightness in paper is due to presence of iron oxide and unburned carbon in fly ash. The non-magnetic fraction has drastic reduction in iron oxide (70-75%), which improves paper strength quality. Fly ash as a material is siliceous or aluminous with alkaline nature and has average specific surface area is 1.40 m^2/g.
3. The properties of fly ash (non magnetic fraction) have been shown in table 1. The pH of the fly ash also falls in between the range of commercial fillers.

Table 1
Properties of fly ash (non magnetic fraction) and Kaolin clay

Parameters	Average Value	
	Fly ash	Kaolin clay
1. Mean particle size, µm	19	7.0
2. Bulk density, Kg/m^3	800	710
3. Brightness, % ISO	29.4	90.4
4. pH	8.8	6.8
5. Specific surface area, M^2/g	1.40	7.2
6. Refractive index	1.65	1.55
7. Color	Grey brown	White

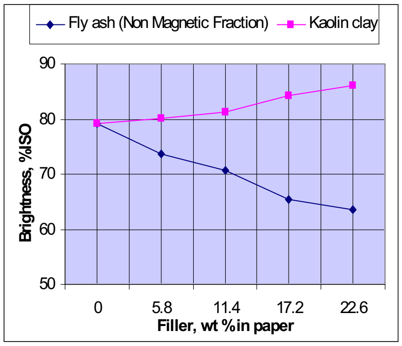

Figure 1: Effect on brightness of paper

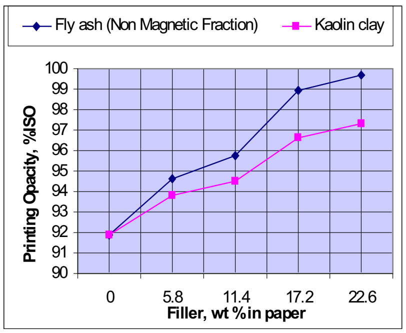

Figure 2: Effect on printing opacity of paper

4. Effect of filler addition on optical properties: Brightness of paper with fly ash as filler decreases with increase of filler percentage due to lower brightness of fly ash in comparison to kaolin clay. This is shown in Figure 1. But the printing opacity is remarkably higher for fly ash loaded paper and the difference increases with increase of filler percentage as shown in Figure 2.
5. Effect of filler addition on mechanical strength properties: Burst strength index of paper loaded with fly ash is nearly equal to the burst strength index of paper loaded with kaolin clay as shown in Figure 3. Comparative study of effect of addition of

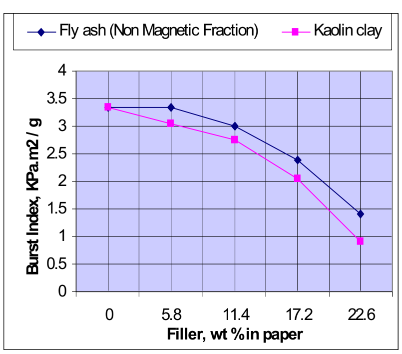

Figure 3: Filler effect on burst index of paper

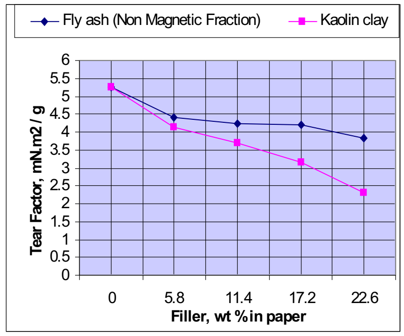

Figure 4: Filler effect on Tear factor of paper

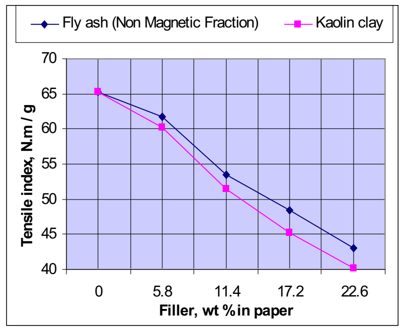

Figure 5: Filler effect on Tensile index of Paper

fillers on tear factor is shown in figure 4. Decrease in tear factor with increase of filler percentage is lower for paper loaded with fly ash in comparison to paper loaded with kaolin clay. So fly ash loaded paper has higher tear factor than kaolin clay loaded paper specifically at higher filler percentage. Paper with fly ash shows better tensile index at higher percentage of filler addition as shown in figure 5.

6. Effect of filler addition on porosity and smoothness of paper: Porosity of paper (measured as Gurley porosity) with fly ash as filler is nearly equal to the porosity of paper with kaolin clay up to 5.8% filler content in paper as shown in Figure 6. At higher filler content, fly ash added paper shows lower value of porosity in comparison to clay added paper. Comparative study of effect of addition of filler on Bendtsen roughness (ml/min) for fly ash and kaolin clay added paper is shown in Figure 7 and 8. Fly ash added paper has higher Bendtsen roughness than kaolin clay added paper. Both the fillers are showing the similar trends of decrease of roughness of paper with increase of filler loading in paper.

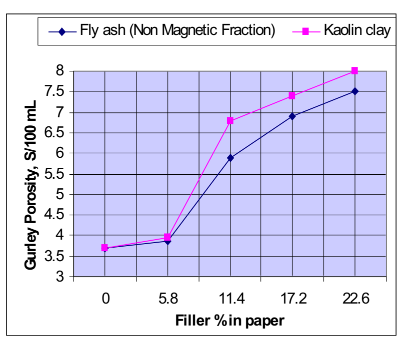

Figure 6: Filler effect on porosity of paper

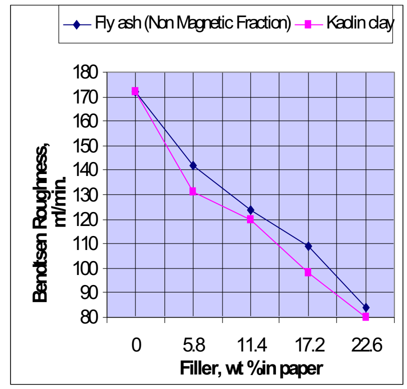

Figure 7: Filler effect on top side smoothness of Paper

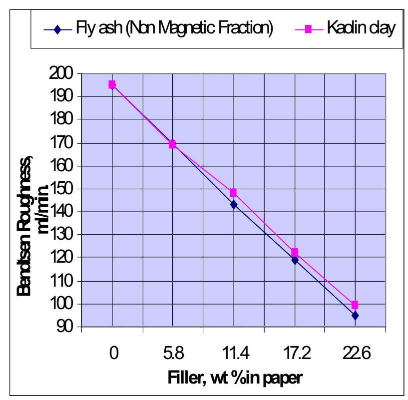

Figure 8: Filler effect on wire side smoothness of paper

7. Economic & environmental Benefits: Utilization of coal fly ash provides the negligible cost of fly ash in comparison to other fillers used in paper, so it will decrease cost of paper significantly depending upon percentage use of filler in paper. Secondly, it will result in higher opacity of paper for same filler percentage in paper. Mechanical strength properties are superior to that of kaolin clay added paper. It will boost environment friendly use and pollution caused by fly ash.

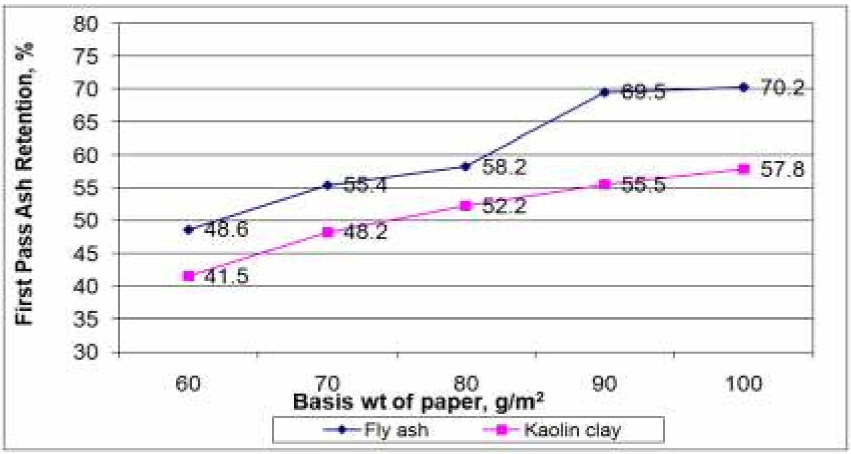

Figure 9: Comparison of Retention of Fly ash and Kaolin clay fillers in paper

8. Retention of fillers: Retention of fly ash is higher than that of kaolin clay due to higher size and irregular particle size. This has been shown in figure number 9.
9. Suitability of fly ash as filler in acid/ neutral/ alkaline internal sizing: The present study has been done mainly for laminate grade papers where high absorption (klem value) is required. But for other grades where internal sizing is required for controlling the water absorption, fly ash is more suitable for alkaline sizing due to having pH (8.8) in alkaline range. It can be used for neutral and acidic sizing also as it is a mixture of inert oxides which are already being used as fillers in paper manufacturing.

Conclusion:

1. The major constituents of fly ash are similar to kaolin clay and other oxides used as filler.
2. Iron oxide and other magnetic fractions can be removed by magnetic separations.
3. The comparative study of effect of fly ash and kaolin clay fillers highlights that printing opacity and tear factor are higher in case of fly ash.
4. The grey color with low brightness is major hurdle for the use of fly ash in white paper. But it is suitable for use in brown, grey and other dark color paper and boards.
5. It provides better opacity and strength properties,
6. Other properties like burst index, tensile index and smoothness are nearly same.
7. Laminate base paper is the best example. so it may improve the quality of laminate base and other colored papers. This may convert fly ash from an environmental pollutant to resourceful material for paper industries.
8. Fiber and fly ash filler composites may be used in a number of applications for laminate and board manufacturing.
9. Fly ash has limitations for use as fillers in food packaging and hygiene related grades of papers due to presence of traces of heavy metals and radioactive materials coming from different grades of coal.
10. Unburned carbon present in small amount (0.01 to 0.5%) are separated to large extent in coarse fraction of fly ash during screening. As it is the limitation for its broad use as filler in paper manufacturing.

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