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Application of Calcium Silicate as Filler in Light Paper

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ABSTRACT

In this study, the effects of porous calcium silicate extracted from high aluminum fly ash on slurry and paper properties were investigated and compared with calcium carbonate. The results showed that the thickness of light paper loose increased significantly after filling with porous calcium silicate. When the filling amount increased, the thickness of paper loose increased.

Keywords: ***Porous calcium silicate; Filler; Light paper.***

Introduction

Light paper is light offset paper, is a more humanized paper, its quality is light, does not contain fluorescent whitening agent, high mechanical pulp content, environmental protection and comfort, in Europe, America and Japan and other developed countries, more than 95% of the books are printed with this paper. Books made of light paper are about one-fourth to one-third less heavy than those made of plain paper, which facilitates readers and saves shipping and mail-order costs.

For the production of light paper, how to increase the amount of paper filling and keep the paper loose thickness is a key issue, the use of filler is very important in light paper production. Whether calcium carbonate, kaolin or talc powder are used as paper filler, because of their different surface properties and morphology, such as surface polarity, surface chemical composition, surface energy and so on, resulting in weak interaction between the two, poor interfacial adhesion, low retention rate of filler when used for paper filling, decreased paper strength and printing powder, hair loss and other problems. The porous calcium silicate prepared by high aluminum fly ash is a kind of porous material with good dispersion, small density and stable size. The filler has good binding property with fiber. The porous calcium silicate has the advantages of inorganic filler, enhancement and retention, and shows excellent comprehensive performance. According to the previous research and production practice, the application of porous calcium silicate filling can obviously increase the amount of paper filling and loose thickness, and can significantly reduce the concentration of white water.

In order to improve the loose thickness of paper, chemical mechanical pulp is used to produce light paper. In addition, paper filling is generally relatively low, paper ash is generally less than 20%, because too high filling will significantly reduce paper loose thickness. Therefore, it is an important problem for light paper production enterprises to increase paper filling and reduce production cost under the premise of keeping paper high loose thickness.

1 The experiment

1.1 Experimental raw materials

1.1.1 Pulp raw materials

The pulp used in the experiment was taken from Yueyang paper industry.

The slurry ratio is coniferous wood pulp: CTMP : machine pulp =4%:15%:81%.Pulping conditions: bleaching coniferous wood pulp beating concentration 3.0±0.5%, tapping degree 38±2°SR; Italian poplar APMP machine beating concentration 3.0±0.2%, tapping degree ≥45 °SR; Masson pine CTMP pulp beating concentration 3.0±0.5%, tapping degree 35±2 °SR.

1.1.2 Slurry chemicals

the calcium silicate filler, taken from the calcium silicate production line of resources company, the main physical index is shown in table 1; calcium carbonate filler, taken from Yueyang forest paper, the main physical index is shown in table 1; AKD slurry sizing agent, taken from terry company; CPAM retention agent, taken from Shenzhen Sanlixing company.

1.2Main experimental instruments and equipment

Stainless Steel Standard Screen, Paper Molding Machine, Finnish soft roller calender, Zeta potentiometer, Mike's White Measure, BTG dynamic water filter, L&W Tensile Strength Meter, L&W Folding tester and Cobb value tester etc.

1.3 Experimental approaches

1.3.1 Preparation of calcium silicate dispersion

A certain amount of calcium silicate powder and water were weighed and dispersed by high speed disperser, the dispersion time was 15 min-25min, the dispersion concentration was 10%-20%, and then the 150 target screen was used for sieve treatment, and the reserve was used.

1.3.2 Paper copying and performance analysis

The PH value of calcium silicate suspension was adjusted to the range of 7-9. The slurry was prepared according to the design proportion, adding AKD sizing agent, stirring 5 min, adding calcium silicate or calcium carbonate filler, stirring 3 min, adding CPAM retention agent, stirring 2 min, measuring the water filtration performance, Zeta potential, electrical conductivity of the slurry, and copying 70 g／m² light paper online. then treated by pressing, drying, constant temperature and humidity. The optical properties, strength properties, retention rate and water resistance of calcium silicate filled paper were measured.

2 Results and discussion

2.1 Comparative Analysis of Packing Properties

The basic physical properties of calcium silicate raw materials were analyzed and compared with white mud light calcium and commercial light calcium and heavy calcium used in the production of yue paper light paper. the results are shown in table 1.

physical index		Calcium sillicate	Lime cake PCC	Commodity PCC	Commodity GCC
Apparent whiteness（ISO）%		87.8	89.5	94	95.2
powder particle distribution %	D90	75.1	24.31	—	—
	D50	39.8	7.08	—	—
	D10	11.9	1.49	—	—
Abrasion value mg/2000次		1.2	—	9.0	14.7
Oil factor mL/100g		163.5	—	71.0	67.7
Specific area m^2/g		132.8	—	21.6	19.7
Porosity mL/g		0.38	—	0.01	—
True density g/cm^3		1.1-1.3		2.5-2.7	
PH value（20%）		10.3	9.1	9.0	9.3

Table 1 Comparison of Physical Properties of Fillers

In general, compared with the filler commonly used in light paper production, calcium silicate has the characteristics of low density, low wear value, large specific surface area, and high oil absorption value.

The specific surface area of calcium silicate is 6.1-6.7 times of commercial PCC or GCC, and the porosity is 38 times of commercial PCC, which indicates that calcium silicate filler has the characteristics of obvious difference from ordinary calcium carbonate filler, and the surface has very many pores, which is beneficial to improve the loose thickness of paper.

2.2 Effect of different calcium silicate on the properties of light paper

The amount of calcium silicate added was 0,14.5%,19.5%,24.0%,28.5%,33.0%, respectively, and the amount of AKD kg/18 tons of pulp (because there was no white water recovery, the amount of laboratory paper 18 kgAKD/t pulp was about equal to the amount of mass production 12 kg/t pulp), and the amount of CPAM was 0.2 tons of pulp. The experimental results and data are shown in Table 2.

It can be seen from table 2 that with the increase of calcium silicate filling, the loose thickness of light paper increases significantly, which is due to the low density of calcium silicate and high porosity, which reduces the binding between fibers, and thus improves the loose thickness of paper. Experimental results show that calcium silicate used in light paper can significantly improve the most critical characteristic index of light paper ——— loose thickness. In addition, when calcium silicate is added, the air permeability of light paper increases rapidly,the air permeability was 4 times that of the blank sample under 33% filling, which indicated that the addition of calcium silicate greatly increased the porosity of light paper and also reflected the increase of loose thickness of paper.

Water resistance is a very important index of light paper, too high Cobb value will lead to paper deformation, difficult to print and other problems, the actual production of light paper Cobb value requirements ≤45 g/m2.. The results of Table 2 show that the cobb value of paper increases obviously after adding calcium silicate filler in the pulp, especially with the increase of filling quantity, the water absorption of paper increases gradually, but in general, the Cobb value of paper is within 45 g/m2, which belongs to a reasonable range. According to the preliminary results, good water resistance can be obtained by adding calcium silicate to AKD slurry.

For paper strength properties, ash content and retention rate, with the increase of calcium silicate filling, the paper's folding resistance, fracture length decreased rapidly, which is because calcium silicate is a mineral filler, retained in the paper page hinders the binding between fibers, thus reducing the strength of the paper page, the higher the filler content, the more obvious the paper page strength decreased. From the following ash analysis, it is shown that the decrease of strength is obviously related to the ash content of paper. The higher the ash content, the lower the strength, the higher the filling ratio and the lower retention rate, which indicates that the amount of calcium silicate filler should be controlled within a reasonable range, not the more added, the better, which is consistent with all the packing properties

Table 2 Effect of different calcium silicate on the properties of light paper

Calcium silicate dosage \Tons of slurry	0	14.5%	19.5%	24.0%	28.5%	33.0%
Ration g/m²	71.0	67.8	67.9	71.4	70.3	70.0
Thickness um	189.4	199.2	205.4	214.4	223.2	224.8
Bulk, cm³/g	2.67	2.94	3.02	3.0	3.18	3.21
ISO Whiteness %	70.4	71.5	72.09	72.26	72.24	72.54
CIE Whiteness %	31.03	35.53	37.41	39.08	39.8	40.61
Opaqueness %	87.13	88.19	88.45	89.99	90.04	89.85
L	92.91	92.92	93.01	92.89	92.76	92.83
a	-0.68	-0.76	-0.75	-0.57	-0.47	-0.49
b	11.17	10.2	9.84	9.42	9.19	9.06
Air permeability mL/min	1185	2335	2855	3160	4095	4925
Cobb values g/m²	20.7	25.2	27.5	37.8	44	35.2
PPS, μm	8.885	8.955	8.86	9.03	9.135	9.12
Folding strength, Times	8.5	3	2	1.5	1	1
Fracture length km	2.85	2.085	1.765	1.74	1.475	1.465
Ash content %	2.83	10.77	12.24	14.93	17.2	19.9

2.3 Effect of calcium silicate and calcium carbonate on the properties of slurry and paper2.3.2

Effects of calcium silicate filler and calcium carbonate (commercial pcc) filler on slurry properties and paper properties were studied. Fillings were 19.5% and 24.0%, respectively. The properties of slurry zeta、 water filter and paper were measured and compared.

2.3.1Effect of calcium silicate and calcium carbonate on slurry filtration

Table 3 shows that the water filtration rate of calcium carbonate filler is higher than that of calcium silicate filler under the same filling amount, indicating that the water filtration performance of calcium carbonate is better than that of calcium silicate. In the application of calcium silicate filler, the dehydration performance of paper pages is slower than that of calcium carbonate filling, but this difference has little effect on the production process, and the drying curve of paper machine needs to be adjusted properly in the production process to ensure the final paper drying degree.

2.3.2 Comparison of performance between calcium silicate and light paper filled with calcium carbonate (unpressed)

The effect of calcium silicate and calcium carbonate on the properties of light paper was studied experimentally. After 5 kg of press and 5 min, of drying, the paper was pressed and dehydrated.

It can be seen from table 4 that under the same amount of filling, the thickness of calcium silicate added light paper loose is much higher than that of calcium carbonate added light paper, and the thickness of calcium carbonate added light paper loose is 2.63-2.64 cm3/g, while the thickness of calcium silicate added light paper loose can reach 3.0 cm3/g, which shows the unique advantages of calcium silicate used for light paper filling on loose thickness. whiteness, calcium silicate added after filling whiteness is low, this is due to calcium silicate whiteness is lower than calcium carbonate, but light paper want to keep this white or beige, so the whiteness requirements are not high. The water resistance analysis showed that the calcium silicate filler can obtain better water resistance by sizing in the slurry, but the effect is slightly lower than that of calcium carbonate filling.

For paper strength, under the same amount of filling, the folding resistance and crack length of calcium silicate light paper are obviously lower than that of calcium carbonate light paper, which is because calcium silicate light paper has higher ash content. The results show that the use of calcium silicate filling will greatly increase the retention rate of fillers, which is conducive to reducing production costs and cleaning white water

Packing dosage Tons of slurry	19.5% $CaSiO_3$ stuffing	19.5% $CaCO_3$ stuffing	24.0% $CaSiO_3$ stuffing	24.0% $CaCO_3$ stuffing
Water filtration rate g/60s	478	506	434	464

Table 3 Comparison of the filtration rate of calcium silicate and calcium carbonate

Packing dosage /Tons of slurry	0	19.5% $CaSiO_3$	19.5% $CaCO_3$	24.0% $CaSiO_3$	24.0% $CaCO_3$
Quantify,g/m2	71.0	67.9	70.5	71.4	70.1
Thickness ,um	189.4	205.4	185.2	214.4	185.2
Bulk ,cm3/g	2.67	3.02	2.63	3.00	2.64
IOS Whiteness,%	70.4	72.1	75.1	72.3	74.5
CIE Whiteness,%	31.0	37.4	43.6	39.1	41.4
Opaqueness,%	87.1	88.4	89.7	90.0	89.6
L	92.91	93.01	94.04	92.89	94.01
a	-0.68	-0.75	-0.78	-0.57	-0.85
b	11.17	9.84	9.11	9.42	9.57
Air permeability,mL/min	1185	2855	1245	3160	1340
Cobb values,g/m2	20.7	27.5	29.4	37.8	27.2
PPS,um	8.89	8.86	8.66	9.03	8.73
Folding strength ,Times	8.5	2	4.3	1.5	3.5
Fracture length,km	2.85	1.765	1.97	1.74	2.11
Ash content ,%	2.83	12.24	8.9	14.93	10.44

Table 4 Comparative analysis of the effects of calcium silicate and calcium carbonate on the properties of light paper

2.3.3 Comparison of performance between calcium silicate and calcium carbonate in light paper (after calendering)

Experimental calendering of the paper pattern in 2.3.2 with a calendering pressure of 10 kg/cm, to improve the internal bonding strength of the paper. the experimental results are shown in table 5.

Packing dosage /Tons of slurry	19.5% $CaSiO_3$	19.5% $CaCO_3$	24.0% $CaSiO_3$	24.0% $CaCO_3$
Quantify,g/m2	66.5	67.7	73.1	71.5
Thickness,um	146.5	142.3	150.6	142.7
Bulk,cm3/g	2.20	2.10	2.06	2.00
IOS Whiteness,%	72.5	74.2	73.2	74.5
CIE Whiteness,%	38.2	41.9	41.0	42.6
Opaqueness,%	87.6	89.1	90.1	91.0
L	93.14	93.70	93.23	93.78
a	-0.81	-0.85	-0.61	-1.00
b	9.75	9.27	9.19	9.16
Air permeability,mL/min	1930	1160	1410	854
PPS,um	6.65	6.52	5.76	6.60
Folding strength,Times	2.7	6.3	3.3	5.3
Fracture length,km	2.42	3.12	2.37	2.81
Ash content,%	12.24	8.9	14.93	10.44

Table 5 Comparative Analysis of the Properties of Light Paper Pages with Calcium Silicate and Calcium Carbonate (After Calendering)

It can be seen from Table 5 that the thickness, loose thickness and air permeability of light paper are obviously reduced after soft calendering treatment, but the loose thickness and air permeability of calcium silicate added light paper is still higher than that of calcium carbonate added light paper, but the increase is obviously reduced, which indicates that calcium silicate added light paper has strong finishing property. After calendering treatment, the strength of light paper is obviously improved, which indicates that calendering improves the bonding between fibers and is beneficial to improve the strength of light paper.

2.4 Effect of calcium silicate filling on AKD sizing performance

2.4.1 Effects of different AKD dosage on water resistance of light paper

Cwhether the high porosity and absorbability of calcium silicate will affect the sizing effect of AKD and reduce the water resistance of light paper is very critical. The water resistance of light paper filled with calcium silicate at different AKD dosage was studied. The akd addition amount was 12 kg/t slurry and 18 kg/t slurry, and the calcium silicate filling amount was 24.0%. The experimental results are shown in Table 6.

KAD addition	18kg/t Thick liquid	12kg/t Thick liquid
$CaSiO_3$ addition,Tons of slurry	24.0%	24.0%
PH value	8.61	8.63
Cobb values,g/m2	32.7	38.1

Table 6 Effects of different AKD dosage on water resistance of light paper

we can see from table 6 that when the amount of calcium silicate added is 24.0%, and the amount of AKD added is 12 kg/t pulp ,18 pulp, the Cobb value of paper is less than 40 g/m2, and the water resistance effect is better, which can meet the requirements of offset printing. The sizing effect of 18 kg/t slurry AKD is better than that of 12 kg/t slurry. Experimental results show that good sizing effect can be obtained by adding calcium silicate and filling light paper with AKD pulp.

2.4.2 The effect of different PH on AKD sizing effect

AKD sizing agent is suitable to obtain good results under alkaline conditions, and too high PH value will also affect the sizing effect. because the calcium silicate filler contains more residual alkali, it will increase the PH value of the slurry system. therefore, the sizing effect of calcium silicate plus light paper under different PH values was experimentally studied. the results are shown in table 7.

KAD addition	18kg/t Thick liquid	18kg/t Thick liquid	12kg/t Thick liquid
$CaSiO_3$ addition tons of slurry	24.0%	24.0%	24.0%
PH value	8.61	10.41	8.63
Cobb values,g/m2	32.7	37.4	38.1

Table 7 The effect of different PH on AKD sizing effect

Table 7 shows that too high PHvalue under the same sizing amount will reduce the AKD sizing effect. in addition, too high paper PH value, long-term preservation may cause false sizing or sizing reversal, resulting in water resistance reduced or completely lost water resistance. And the results show that PH value regulation is very important for calcium silicate filling.

3 Conclusion

(1) Compared with calcium carbonate filler, the retention rate of calcium silicate filler increased greatly, which can effectively reduce the concentration of white water.

(2) The application of calcium silicate to light paper filling can greatly increase the thickness of light paper loose, and the calendering process should be controlled well in production, which will help to improve the quality of products and increase economic benefits.

(3) When the paper is filled with calcium silicate, it can get good sizing effect by using conventional AKD sizing. The AKD dosage is estimated to be 12-15 kg/t pulp.

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