Application of Composite Addictives in Paper-Making Using Slag-wool Fiber

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Abstract

The composite paper was made successfully from the heterogeneous mixture of common pulp and slag-wool fibers, without/with different amounts of composite addictives. These physical properties, including tensile strength, folding endurance, and smoothness, etc., were investigated in detail. All physical properties of the composite paper, made from the 30% slag wool fibers & 70% paper pulp, and no any composite addictive, decrease sharply, in comparison with common paper. While for the same paper with addition of optimum amount (0.5%) of composite addictives, the tensile strength increases by 15%, while the folding endurance, by 40%. Therefore, it is vital to introduce composite addictives in the process of composite papermaking. The aforementioned investigation can reduce the amount of paper pulp, and therefore, protect our forest resource.

Keyword: Blast-furnace slag, Slag wool fiber, Addictive, Tensile strength

1. Introduction

Blast-furnace slag (BFS) is a by-product in the manufacture of pig iron. It is formed by the reaction of limestone with materials rich in SiO_2 and Al_2O_3 at 1350–1550 °C. It has been often used as a pozzolanic admixture in Portland cement paste [Uchigawa, 1986; Mehta 1989; Pal *et al*., 2003; Cheng *et al*., 2003; Barnett *et al*., 2006]. The major components of blast-furnace slag are SiO_2, CaO, MgO, and Al_2O_3.

In China annual granulated BFS production capacity is around 15 million tons, which becomes a threat to the environment [Wang *et al*., 2004]. Therefore, it is vital for China to make the best of BFS. Unfortunately, BFS in China has little application in all fields except for Portland cement. On the other hand, as the second papermaking country [Hu et al., 2001], China has destroyed amounts of forests, together with deadly emission of waste liquid from papermaking process.

As is known, slag wool fibers (SWF) can be produced by means of re-melting and throwing BFS. In the previous report [Zhou *et al.* 1997], SWF can be easily obtained by directly throwing the high-temperature (1300 °C or so) liquid BFS, which is a common industrial waste from steel factory or thermoelectricity factory. As inorganic fibers, SWF is very brittle, difficult to bind with organic fibers. However, unlike plant fibers or traditional filler such as calcium carbonate, SWF can be prepared non-noxiously, without environment pollution. According to report [Nie *et al.*, 2005], SWF can be employed as a new papermaking material between plant fibers and traditional fillers. After superfine ground, SWF gives a length-diameter ratio of 10, with a mean diameter of 10–15 μm, the same size as plant fibers serving as papermaking material. The previous report reveals [Nie *et al.*, 2005] that the SWF substitute range of paper pulp is 10–30%, which can protect the rare forest resource. Besides, the substitute of SWF for common pulp can lower the cost of papermaking and the amount of industrial waste. Commonly, SWF is much shorter and more brittle than plant fibers, which indicates difficult binding between SWF and common organic fibers. In the present paper, the investigation mainly is focused on the home-made composite addictives as new-type paper strength agents. The physical properties, including tensile strength, folding endurance, and smoothness, etc., were studied on different conditions. Our investigation is beneficial to the SWF-plant fibers composite paper, which can be promising to solve the BFS problem, and lower the environment pollution from papermaking process.

2. Experimental

2.1 Materials and reagents

Kraft Pulp: from Russia, 45° Schoppe rriegler (SR); SWF: thrown by high-temperature BFS; and home-made composite addictives

2.2 Equipments

ZT4-00 23 liters laboratory beater; Screen: ZQS5 with ø 300; One-side glazed dryer: CSG 356×457mm; Hand sheet former: ZQJ1-B with ø 200 mm

2.3 Procedures

2.3.1 Preparation of beating and handsheets

Fiber stuff was fully soaked in water. Kraft pulp was beaten up to about 45°SR by ZT4-00 23 beater, with a wet-weight of 6 g. The impurities in SWF, such as sands, can be removed by wet cyclone separator. After that, the SWF was treated by some organic agent, and then beaten by the beater to about 7°*SR*, with the wet-weight of 0.3 g. Both kinds of pulp were mixed according to the ratio, and the SMF was fully dispersed into the plant pulp. After the addictives were added into the composite pulp one by one, and mixed homogeneously, the handsheets were conducted on the sheet former, with the weight of 60 g/m^2. Finally, the formed sheet can be obtained after the handsheets were dried on the one-side glazed dryer [Qu, 1992].

2.3.2 Measurements of beating degree were conducted on the Schoppe Rriegler Apparatus.

2.3.3 Measurements of physical properties of paper were based on the methods listed by *Measurement Standard Compile of Papermaking Industry*.

3. Results and discussion

3.1 Paper properties without composite addictives

For the common paper sheet and that of adding 30% SWF, the physical properties were measured and listed as Table 1.

As illustrated from Table 1, each property indexes are dramatically changed after 30% SWF were added into the composite pulp. That is, the opacity and the thickness increase while the weight is unchanged. Besides, the tensile strength and the folding endurance are much lowered, or rather, the former decrease by 24%, the latter, 90%. Due to short and brittle SWF, as well as difficult to bind with plant fibers, it is reasonable for the strength indexes, such as tensile strength and folding endurance, to be lowered with increasing SWF content. In order to promote the strength of the composite paper solve this problem, it is indispensable to add some composite addictive.

3.2 Effect of composite addictives

3.2.1 Tensile strength and folding endurance

For the composite paper with 30% SWF and different amounts of composite addictives, the tensile strength and folding endurance were measured and shown in Fig. 2 and 3, respectively. With increasing the composite addictive, the tensile strength and the folding endurance dramatically increase, as shown in Fig. 1 and 2. When 0.5% composite addictives is added, the tensile strength is increase by 15%, and the folding endurance, by 40%. With further increasing the composite addictives, both the tensile strength and folding endurance are lowered. As we know, the composite addictives employed are macromolecule polymer. Little amounts of composite addictives can promote the binding between SWF and plant fibers, while large amounts of them will make the composite pulp viscous. That is to say, the large viscousness can trap the fibers dispersion, and lower sheet formation, which lowers strength properties.

From the chemical point, the ammonia, from the composite addictives, combines with hydroxide radical, from cellulose and hemicelluloses molecular, by means of H-bind [Ma *et al.*, 2004]. That is, the cations from molecular absorbs the anions from SWF, which can promote the number as well as the strength of molecular binding, leading to a reversible change of physical property [David *et al.*, 1991; Henry, 1964]. Moreover, due to the presence of electrostatic repulsive force, the composite addictives have a good dispersity, which can make fibers fully dispersed and bound. So, the good dispersity and H-bind can promote paper formation and the physical strength. That is, the paper strength became dramatically increased after adding the composite into the composite pulp.

3.2.2 Other properties

For the composite paper with 30% SWF and different amounts of composite addictives, the physical properties are shown in Table 2.

As shown in Table 2, after the composite addictives were added, little change occurs to the weight, the thickness and the opacity of the composite paper. Generally speaking, these physical properties are concerned with the pulp composition, or rather the content of SWF. Based on the same content (30%) SWF, these properties are reasonably unchanged.

3.3 SEM analysis

SEM was conducted on the composite paper with the 30% content of SWF. The morphologies of SEM are shown in Fig. 3 and 4, respectively.

Comparing Fig. 3 with 4, we can observe the dispersion state of fibers. That is, without the present of composite addictives, the fibers diffuse randomly, while the fibers can disperse homogenously after adding the addictives. Obviously, it is the addition of the composite addictives that can promote the strength indexes of the composite paper. In other words, after added into the paper pulp, the addictives can disperse on the surface of as well as into the fibers, and chemically cross link with the fibers [*Yang et al.*, 2005]. Therefore, the net-like amorphous crossing is formed, which can confine the motion between fibers, and consequently, lower the expanding of fibers and companding deformation of sheets [Wu *et al*., 2005]. The paper strength is obviously improved.

4. Conclusion

Composite paper was made successfully from the heterogeneous mixture of common pulp and slag-wool fibers without/with the presnce of composite addictives. All properties of the composite paper, made from the 30% slag wool fibers and no any composite addictive, decrease sharply, in comparison with common paper. While for the paper with addition of optimum amount (0.5%) of composite addictives, the tensile strength increases by 15%, while the folding endurance, by 40%. Therefore, it is vital to introduce composite addictives in the composite paper making, which can reduce the amount of pulp, and therefore, protect our environments.

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Table 1. Comparison of physical property indexes of paper sheets without/with adding 30% SWF

SWE content (*%*)	Weight (*g/m²*)	Thickness (*mm*)	Whiteness (*%*)	Tensile Strength (*Km*)	folding endurance (*Time*)	Smoothness (*Sec*)	Opacity (*%*)
0	61.01	0.119	78.45	5.01	465	9.1	76.5
30	59.96	0.139	76.9	3.80	43	2.9	80.0

Table 2. All physical property indexes of the composite paper after adding the composite addictives

SWF content (*%*)	Addictives content (*%*)	weight (*g/m²*)	Thickness (*mm*)	Whiteness (*%*)	Smoothness (*Sec*)	Opacity (*%*)
30	0.2	62.6	0.149	73.4	0.6	81.5
	0.3	59.2	0.162	70.2	1.6	80.5
	0.4	56.6	0.148	74.2	1.3	78.0
	0.5	63.5	0.160	74.5	1.5	80.0

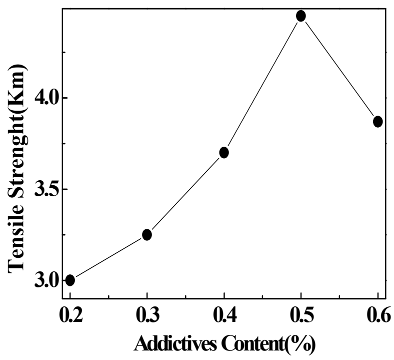

Figure 1. Tensile strength v.s. different amount of composite addictives

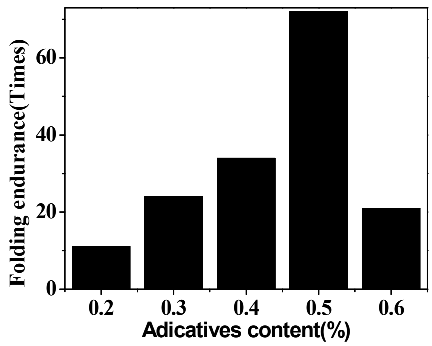

Figure 2. Folding endurance v.s. different amount of composite addictives

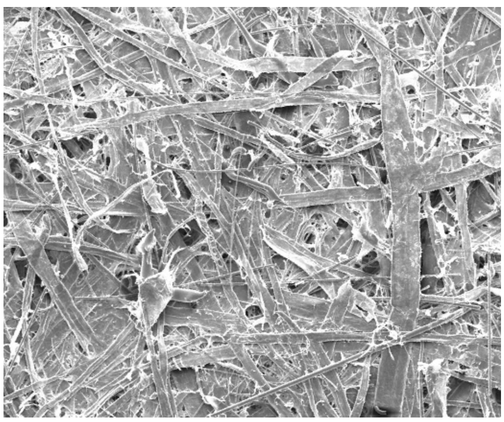

Figure 3. (a) Fiber SEM images without addition of composite addictives

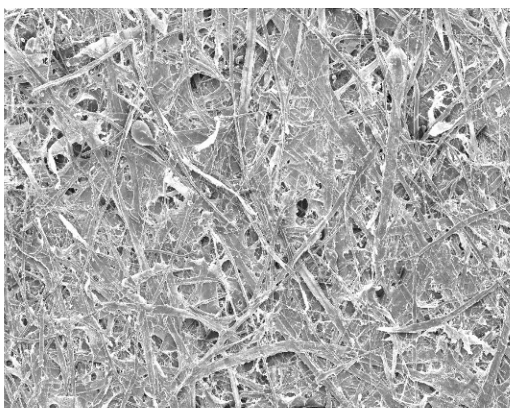

Figure 3. (b) Fiber SEM images with addition of composite addictives