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Study on Branched Polyacrylamide Preparation and Application

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Abstract. With the continuous development of printing technology and printing equipments, the quality of newsprint should be improved to meet with all the real demands. Acrylamide copolymer is used in paper-making as process aid and function aid which can effectively improve paper printing adaptability. Preparation and application of polyacrylamide via aqueous copolymerization was studied as dry strength agent in this paper. The polyacrylamide with middle molecular weight and low viscosity was obtained by reacting acrylamide, cationic monomer [2-(acryloyloxy)ethy] -trimethylammonium chloride and N,N-dimethylaminoethyl methacrylate, anionic monomer itaconic acid, active nonionic monomer N-metholacrylamide and crosslinking monomer 1,3,5-triacryloylhexahydro-s-rine, the copolymer was characterized by FT-IR, charge density and molecular weight distribution. On the basis of internal present situation of pulp, the papermaking system with deinking pulp from office waste paper and white water of 1000-1200us/cm conductivity from paper mill were selected for application research. The results show that when the dosage of acrylamide copolymer is 0.8% to the dry weight of pulp and handsheet basis weight is 60g/m^2, acrylamide copolymer can show the superior performance to newsprint and receivable cost for paper mill, fluffing speed, tearing strength and internal bonds are respectively improved by 14%, 20% and 30%.

Introduction

Secondary fiber is a very important kind of paper making resource because using it has both economic and social benefit, so it is concerned by almost all the world. The possibility to make newspaper by secondary fiber is widely accepted. In papermaking process, acrylamide polymer was extensively used[1]. In the polyacrylamide manufacturing process, ionic monomers are introduced into polyacrylamide in order to fix polyacrylamied onto fiber[2-3]. But in a large number of electrolytes present conditions, ionic groups become invalid. Meanwhile fast development of the papermaking industry still exist many problems, such as deteriorated pulp quality, the impurities raise of whitewater, pH fluctuation of whitewater. In this application, traditional dry strength agents show bad performance and even fail because of combining with excessive impurity, new dry strength agent must be developed to meet demand for papermaking industry.

Printing technology promoting, high-performance printing equipment, printed sheet quality being perfect, such factors all demand paper with higher printability. There are two more effective measures, using additive and surface sizing, to improve paper printability. For this reason, on the basis of the relevant patent[4-7], this paper used active monomer n-methylol acrylamide, cationic monomer, cross-linking monomer, to synthesize amphoteric cross-linked polyacrylamide as dry strength agent firstly, then added the dry strength agent into

pulp to research printability performance improved. In the test, secondary fiber was used to make newsprint, thus it could be close to actual industrial situation, seek how to improve the performance of secondary fiber newsprint, extend the application of the secondary fiber.

Experimental

Materials. Acrylamide, itaconic acid, acryloyloxyethytrimethylammonium chloride, N-metholacrylamide, N,N-dimethylaminoethyl methacrylate, isopropyl alcohol, 1,3,5-triacryloylhexahydro-s-rine, formic acid， ammonium persulfate. (All analytical reagent)

Apparatus. IKA electric mixer: power 90W, speed 60-2000 r/min(manufactured by Guangzhou lab instruments technology company Ltd); Brookfield rotary viscometer: range 1-10^6mPa·s (manufactured by US Brookfield engineering labs INC.); Tear strength tester, CSF tester and IGT tester (manufactured by Sichuang Yangtse river paper instruments Co., Ltd); sheet former, German FRANK Internal bond tester, manufactured by Japan Kumagai Rikikogyo Co.,Ltd.

Preparation Methods. Acrylamide (92.0mol%), itaconic acid(1.0mol%), N-metholacrylamide (2.0mol%), [2-(acryloyloxy) ethy]trimethylammonium chloride (2.0mol%), diallyldimethylammoniu (1.5mol%), N,N-dimethylaminoethyl methacrylate (3.0mol%), a quantity of 1,3,5-triacryloylhexahydro-s-rine, isopropyl alcohol, were placed in the four-necked flask . The pH of reaction mixture was 3.0 approximately by phosphoric acid. In nitrogen conditions, the reaction mixture was heated to 50ºC, then was added ammonium persulfate. The reaction mixture was heated to 80ºC for 1 hour, an aqueous solution of the copolymer was obtained by adding water and then added formic acid.

Analytical methods. FTIR was measured by disc methods of KBr and NICOL ET AVA TAR370 spectrometer, measuring range is 4000～400 cm^{-1}; molecular weight is tested by Waters 2695 GPC; charge density is determined by Mutek PCD03PH.

Results and Discussion

Typical analysis. Appearance: pale yellow viscous liquid, easy soluble in water, viscosity was 1300 mPa·S, solid content was 12.5%, pH value was 3.9.

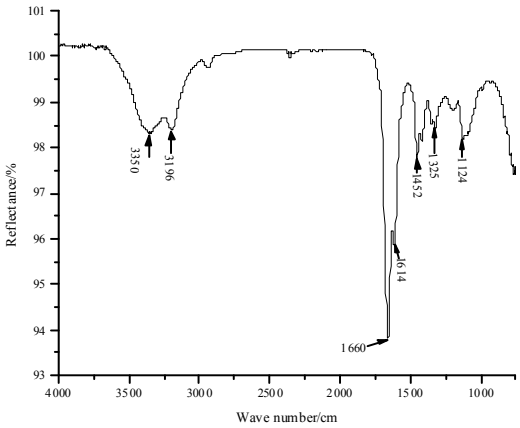

Fig.1 IR spectrum of PAM

PAM FT-IR Characterization. In the FT-IR spectra, 3350cm^{-1} is asymmetrical stretching vibration of –NH_2 from the −$CONH_2$, 3196cm^{-1} and 1660cm^{-1} were symmetrical and asymmetrical stretching vibration of –C=O from the −$CONH_2$, 1452cm^{-1} is flexural stretching vibration of –CH_2 in ploymer, 1325cm^{-1} was flexural stretching vibration of –C-N from the −$CONH_2$, 1124cm^{-1} was stretching vibration of −C-O-.

From the analysis result, the main monomer of the polymer was acrylamide, so the infra-red reference spectra of the polymer was very close to pure acrylamide polymer, at the same time vibration zone of anionic monomer's –COOH and cationic monomer's -COO- were all near by the vibration zone of -$CONH_2$, those characteristics were not obvious in the polymer spectrum.

PAM Molecular Weight Determination. Fig.2 showed molecular weight distribution of synthesized acrylamide copolymer. The average molecular weight was 12 million. Because local waste was recycled many time which caused bad strength and contained a lot of fines, PAM with

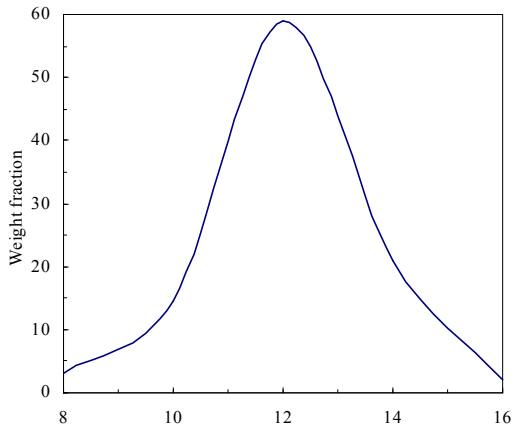

Fig.2 Molecular weight distribution of PAM

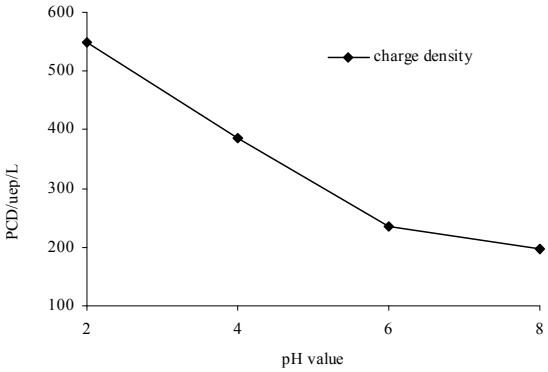

Fig.3 Influence on PCD

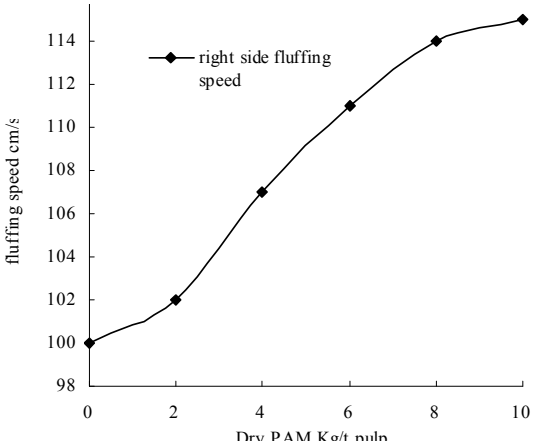

Fig.4 Influence on fluffing speed

middle Mw can give sheet more bonding points and higher strength. Meanwhile PAM with special amphoteric ions can form ionic complex to be good for enhancing applied molecular weight and Mw volume, which make PAM better fix on fibers.

PAM Charge Density. Fig.3 showed that, with pH changed in papermaking system, charge of dry strength agents decreased rapidly, however, there was a little change in neutral and alkaline conditions. In waste paper making system, it contained large amounts of filler, especially calcium carbonate most used, so pH value of the solution were always neutral or alkaline. Stationary positive charge of the dry strength agent contributed to fix on negative fiber.

Application Conditions. Papermaking Condition: The basic weight was 60g/m^2, the wire was 80 mesh, pH value of white water was 6-7, press pressure was 5kgf/cm^2 for 1 min, the handsheet samples were dried at 100ºC for 2 min.

3% pulp slurry consisting of 80% local deinking pulp from newsprint and 20% imported bleached kraft pulp was diluted with white water (conductivity 1200μs/cm), stirring speed 400 r/min, 1.0% (on the basis of absolute dry pulp weight) cationic starch was charged at 1 min. 0.2%, 0.4%, 0.6%, 0.8%, 1% (on the basis of absolute dry pulp weight) polyacrylamide sample was charged at 2 min. The portion of the slurry was diluted to 1.0% consistency at 3min and then was made into sheet by former.

Influence of PAM on paper fluffing speed. The results were shown in Fig.4, the more usage of PAM, the better paper surface strength. When the usage of PAM was less than 0.4% in volume of paper, the critical fluffing speed was nearly linear augment; When the usage PAM was more than 0.8% in volume of paper, the critical fluffing speed was slow augment, and the increase of production cost, taking into account the adverse impact on paper evenness, did not need to continue to increase the volume of mixture. From the figure, added dry strength agent into paper which could improve newsprint critical fluffing speed effectively.

Influence of PAM on paper tearing strength. Tearing strength of sheet is mainly affected by average fiber length, Secondly, fiber bonding and fiber strength. In the papermaking process dry strength agent can effectively increase the fiber bonding. Fig.5 showed that, when the dry strength agent added was less than 0.6%, tearing strength with the increase of dry strength agent obviously increased; dry strength agent dosage was higher than 0.6%, tearing strength increase became slowly, because when the dry strength agent was added to some extent, evenness of sheet was impacted, therefore, too more dosage of dry strength agent was not obvious to increase paper tearing strength. In additional, more dosage would decrease cost-effective.

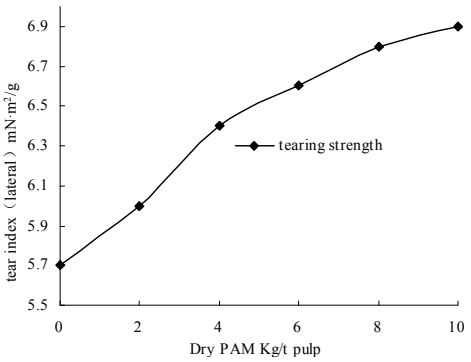

Fig.5 Influence on tearing strength

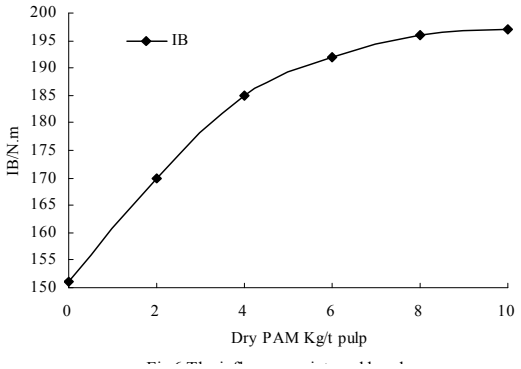

Fig.6 Influence on internal bonds

Influence of PAM on paper internal bonds. The results were shown in Figure 6, usage of the dry strength agent brought improvement of internal bonds, it was a tendency of internal bonds from rapid increasing to gently increasing until max. Because dry strength agent improved chemical linkage force and contact surface area among fiber, combined fiber and filler to become aggregates and improved paper evenness. But in high conductivity system, electrolytes, sticks, resin and filler took effect together, meanwhile the retention ratio of filler in paper would promote up to the maximum mutual synergism, promotion of internal bonds became slow and limited.

Conclusions

Polyacrylamide dry strength agent at lab with high molecular weight and low viscosity and more bonding points was obtained by improvement of synthetic process. The configuration of polyacrylamide contained groups of quarternary ammonium salt and amine salt with acid and carboxyl, the web configuration of polyacrylamide was obtained by crosslinking reaction of triacryloylhexahydro-s-rine among chains. It could improve newsprint strength by application of above acrylamide copolymer. When the dosage was 0.8% of dry pulp, acrylaimde copolymer showed the superior performance for sheet, fluffing speed of right side was 114cm/s, tearing strength of cross machine was 6.8mN·m^2/g, internal bonds was 196N·m.

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