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Discussion on digitalization of Paper Fiber

Abstract. *This paper introduced several testing methods of paper fiber parameters, such as projector method, microscopy method, polarized light method and grating method, and also compared the advantages and disadvantages of these methods. In order to express fiber distribution quantitatively, it put forward the idea of taking integrated multifunctional sensor of detection, judgment, self diagnosis, data processing and adaptive ability to test the distribution of paper fiber. It attempted to get the two-dimensional image of paper fiber distribution by this sensor, then used this image to analyze paper fiber parameters such as quantity, length, thickness, opacity, x-values distribution and y-values distribution, and discussed method of analyzing digitalization of paper fiber.*

Streszczenie. *W artykule opisano szereg metod analizy włókna papieru – głównie metody optyczne. Jak rezultat analizy proponuje się dwuwymiaropwy obraz struktury włókna. (**Metody cyfrowego przedstawiania włókna papierowego**)*

Keywords: Paper; Fiber; Digitization; Discussion .
Słowa kluczowe: włókno papierowe, analiza cyfrowa.

Introduction

Paper plays an important role in all aspects of human development, especially in culture, science, industry, agriculture, national defense and commerce. Through the application of paper, human knowledge and information are spread rapidly, and long historical heritage is well inherited so as to promote rapid development of science, culture and other industries. In developed countries, paper industry has become one of the ten pillar industries. In our country, with the development of national economy and improvement of the living standards, the development of paper industry is becoming increasingly important [1].

Paper is an important means of subsistence and production. It is closely related to every field in modern life. Without paper, the development of human society will be severely obstructed; without paper, there can be no human society civilization to speak of; without paper, the inheritance of long history of Chinese nation will be hopeless. So pulp and paper industry is an important industrial department which relates to national economy and the people's livelihood. In the process of papermaking, fiber will be arranged along the direction of paper machinery operation, while the condition of fiber arrangement and interweaving influences the flatness and smoothness of paper surface. The paper which is interweaved badly will generate mottling in the printing process. Pulp is a kind of fibrous material which is prodeced from plant fiber through different processing methods. According to different processing methods, it is divided into mechanical pulp, chemical pulp and chemimechanical pulp; according to different fiber materials, it is also divided into wood pulp, straw pulp, jute pulp, reed pulp, cane pulp, bamboo pulp, rag pulp and so on; according to different purities, it is divided into refining pulp, bleached pulp, unbleached pulp, high yield pulp, semi-chemical pulp and so on. It is generally used to produce paper and paperboard. In addition to produce specialty paper, refining pulp also is a kind of raw material to produce cellulose derivative such as cellulose ester and ether. It is also used to produce artificial fiber, plastic, painting, film, gunpowder and so on. With the development of global digital technology, people start to put digital research of paper fiber to agenda. It meets the need of the development of modern society.

Fiber Analysis of Paper

Paper is made up of plant fiber, stopping, sizing and pigment. Plant fiber is divided into four kinds:[2]

A.Stem fiber: straw, wheat straw, reed, bamboo and so on.

B.Wood fiber: pine, spruce, birch and so on.

C.Bast fiber: flax, hemp, cotton bast, mulberry bast and so on

D.Seed fiber: cotton, rag and so on.

Paper fiber parameters include length, roughness, categories, ratio and so on. If these indexes are used as quality parameters, it is of lesser significance. However, it is of significance if the length of fiber is connected with thickness of cell wall and fiber diameter. Fiber dimensions such as length, width, cell wall thickness and roughness are all interrelated, so its combination properties have a great difference on papermaking.

1) The length of fiber

The fiber length of paper generally refers to mass weighted fiber length. It is related to many intensity properties, but it will damage the homogeneity of paper formation when the paper reaches a certain length and then increases more. Wider and thicker macrofiber can increase the stiffness of the paper, uniform Length can increase the strength of the paper, but long fiber makes negative effects on the evenness of the paper. It is believed that the length of fiber is one of the most useful specifications in providing pulp and paper strength. Now microscope is mainly used to measure weighted fiber length.

2) The thickness of fiber

Fiber thickness refers to the weight of per fiber length, expressed with the weight of 100m long fiber which is absolutely dry. Thickness is the same important as fiber length in paper-making, but it is rarely used because of the difficulty to measure it. The thickest fiber used in paper-making can be more than 30mg/100m, while the finest fiber is less than 10mg/100m. Fiber thickness has a significant impact on the most strength properties, liquid or air permeability and surface smoothness. It is really a trouble to measure the fiber thickness with a microscope. But the fiber analysor "FiberLab" can be used to measure the fiber thickness with digital model, so researchers usually use it to measure the fiber thickness.

3) Types of fibers

Fiber categories are the direct factor which influences paper properties. Therefore, determining which fiber is used in papermaking has significant impact on knowing paper properties and productive technologies. The main principal of observing and determining fiber categories with high magnification optical microscope is that different kinds of fiber have different forms, while the same kind of fiber has almost the same form.

The specific method of determining fiber category is: firstly put the dispersive fiber onto the glass slide equably, after drying, uses Herzberg reagent to dye them. Many fibers have color reactions with this reagent. For example: hardwood and softwood fiber are dark blue, while flax fiber is rose. These color reactions are also important basis to determine fiber category.

4) The ratio of fibers

Nowadays, lots of paper is produced with many kinds of pulp, so knowing the composition of pulp is very helpful for us to research paper productive technologies. The ratio of fibers in paper will have great inspiration on knowing compounding ratio of the pulp used in papermaking. Generally, fiber ratio is measured by projector method. After determining the fiber category, colored glass slide is put on the projector to measure each single fiber length manually, about 200~400 in total. Then its ratio is calculated according to gravimetric factor of different kinds of fiber. In order to prevent affecting reliability of measurement, choose those lens which can represent the fiber distribution trend in the whole film. It should be pointed out that the method can only roughly reflect the fiber ratio of paper, and it can not be used in some highly precise measurement.

Fiber Dectection

In the process of papermaking, fiber will be arranged along the direction of paper machinery operation, while the condition of fiber arrangement and interweaving influences the flatness and smoothness of paper surface. The paper which is interweaved badly will generate mottling in the printing process. In order to detect the interweaving condition of fiber, paper is usually held to the light. The light filters the paper and then according to it to judge the fiber uniformity. In recent years, SEM, EDS and WDS are also good ways to test and analyze paper surface structure and observe fiber interweaving situation.

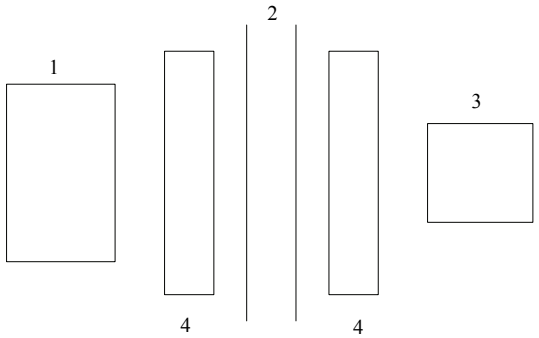
1.Methods of fiber detection

Nowadays ways of detecting paper fiber are mainly projectors, microscope, polarized light method and grating method. KaJaani Electronics Co., Ltd.in Holland has successfully developed two kinds analyzers that can measure fiber length fast: FS-100 and FS-200. The former is tungsten lighting, and the latter one is laser lighting with a higher accuracy. They can complete the length analysis for thousands or tens of thousands fiber in a few minutes. It is more accurate and faster than projector or microscope.

1) The pulp fiber detection, which is based on image analysis, is one of the key technologies in pulp and papermaking industry at present. It directly influences paper's quality and becomes a research hotspot. The target of pulp fiber image analysis is to analyze shapes and dimensions of pulp fiber in micro state. According to the edge overlaps caused by the relative uncertainty of fiber shape, the shape is identified and the location and extraction of the edge are improved; for the uniformity analysis, the spatial domain is transformed into frequency domain or wavelet domain to make analysis by image transformation and then obtain its characteristic; for the surface quality deformity, the characteristics of normal or defective structure is extracted by texture analysis, and then the deformity shape of paper surface quality is distinguished using the method based on artificial neural work and statistical pattern recognition method.

2)Measurement of the length of paper fiber—polarized light method GB /T 10336-2002 standard provides a method for measuring the paper fiber length with polarized light. This standard is suitable for measuring all kinds of fiber length of pulp. The fiber fragment less than 0.2mm is not considered as a fiber so the result will not be concluded in the calculation. Its principle is: the fibers, which are suspended on water, flow through a FOC and arrange directionally. Projected length of every fiber is measured automatically. A set of orthogonal polarized light microscopy is used to distinguish fiber from substances outside fiber, such as bubble. Bubble can not make the polarization rotation. So number-average fiber length, weight-average fiber length and length distribution can be calculated.

3) The measuring instrument based on polarized light method is composed of measurement component and the sample delivery system. There is a fiber orientation chamber (FOC) in the measurement component, and the suspended fiber in the liquid, flows through it. There is a uniform light illumination on the one side of the FOC, while a photosensitive array on the other side. Both sides of the FOC are also equipped with orthogonal polarization filters, which are installed between the light source and photosensitive array. Fiber length can detected from the fiber image through photosensitive array, because birefringence light produced by the fiber can go through the second polarizer, and the length of the image is the length of the fiber. The water stream makes the fibers flow directionally through a planar slot or a pipeline, with the pipeline's or planar slot's thickness along the direction of the optical path not being greater than 0.5mm. Figure 1 is the measurement schematic diagram with polarized light method [3].



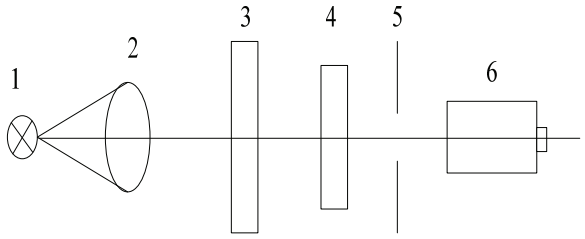
1— Light source; 2—FOC; 3—Photosensor; 4—Polariscope

2—

Fig.1. Measurement schematic diagram with polarized light method

Measurement of paper fiber length (grating method)—QB/T 2597-2003 standard applies to all sorts of measurement of fiber length for paper-making raw materials. The fiber fragment and impurities less than 0.2mm are not considered as fiber so the measurement and statistical results result will not be concluded in the calculation. The principle is: the image on the fiber specimen is enlarged using a projector or a projection microscope, and let it appear on the projection screen. Then the grating displacement sensor is used to move along the fiber image, thus the fiber length can be automatically measured, and then the results are delivered to the computer for statistical calculation. By this way, number-average fiber length, weight-average fiber length and length distribution are calculated.

The length detection of grating fiber is composed of the imaging system and measurement system. The table-type projector or projection microscope is used in imaging system to enlarge the fiber image to 50 times to 100 times. The main components of the measurement system are grating displacement sensor. It's composed of a light source (LED), a condenser, a main grating (moving grating), an indicating grating (fixed grating), a light bar, photodiodes and several other components which is shown in Figure 2.[4]

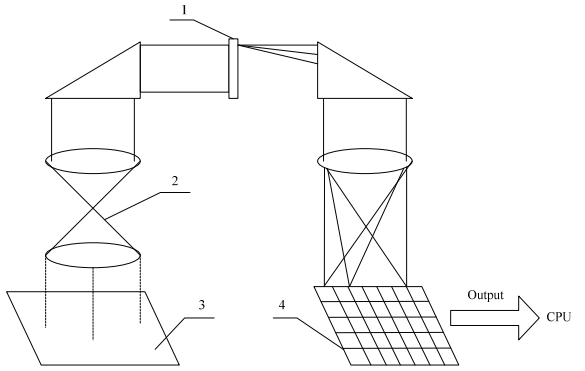


1—Light source;2—Condenser;3—Main grating;4—Instructions grating;5—Light bar; 6—Photosensitive diode

Fig.2. The schematic of grating linear displacement transducer

2. Discussion on digitalization of Fiber

Assume the distribution of paper fibers is detected with the intelligent sensor system. The smart sensor is a combination of “electricity five senses " and "microcomputer". It's a kind of integrative multi-sensor with the capability of testing, determining, self-diagnosing and self-adapting the outside information. The sensor also has the capability of conducting automatic dialogue with the host machine and choosing the best scheme. It also can separate the obtained large amounts of data to achieve long-distance, high speed and high-precision transmission. Figure 3 is the schematic of two-dimensional adaptive image smart sensor. CCD (charge-coupled device) two-dimensional array cameras are used to switch detected image into time series video signal. So that the synchronous signal which is corresponding to the spatial filter is generated in the electronic circuit. Then it multiplies the video signal and integrates with it. Finally through changing the parameters of space filter, moving the grating of filter, the sensitivity is improved and the purpose of two-dimensional sensor is achieved.[5,6,7,8,9]



1—Reflective diffraction optical grating; 2—Optical system; 3—Samples of paper; 4—Two-dimensional light sensor array

Fig.3. Two-dimensional adaptive image intelligent sensor

Computer processing technology can be used to deal with the fiber distribution of paper. The Fighure-4 shows a computer processing diagram of the paper fibers distribution. As is described in the diagram, image signal from the intelligent sensor communicates with the CPU through the interface card, and then the CPU deals with the signal with prescriptive algorithm and prints out the distribution of paper fibers, such as the quantity, the length, the thickness, the transparency, the distribution along the direction of X-axis and Y-axis and so on. In addition, all of the parameters can be set through the keyboard when the signal is processed in the CPU.

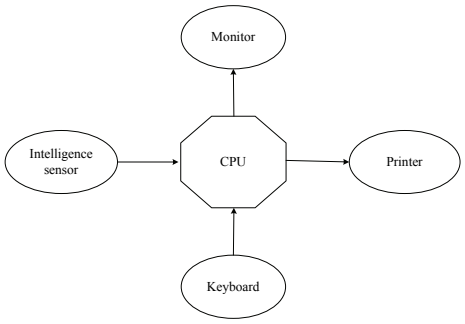


Fig.4. Computer processing schematic of paper fibers distribution

Conclusion

Paper fibers analysis and detection is a complicated work. This paper is only a preliminary study of paper fibers distribution. It is very delicate work. In order to get good measurement results, advanced sensor should be combined with computer technology. Meanwhile the operators are required to explore the experimental phenomenon from outward appearance to inner essence, and then summarize the experimental phenomenon in time so as to have an in-depth understanding the general situation of the paper. By this way, it can provide reference for carrying out the research, optimizing production materials, improving production process and paper performance, and reducing the production cost. At the same time it has significance for the study of special paper.

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