

Development of paper quality parameter measurement in China

LIANHUA HU AND JIN MA

ABSTRACT: Paper quality parameters are important indicators of paper production, such as paper moisture, basis weight, ash content, strength, and so on. This study focuses on the online measurement methods and development of paper basis weight, moisture, and ash measuring.

First, the measurable paper parameters and quality control system products in China are analyzed. Then, the basis weight measurement methods, accuracy, and development are given in the range of 10~1000 g/m². Third, the distinction between infrared and microwave methods for moisture measurement is discussed. Finally, the ash measurement is introduced.

Production and consumption of tissue paper in China have continually increased during the past decade. Near-infrared light technology is mature for the measurement of paper parameters in the range of 10~200 g/m² basis weight. However, the near-infrared online measurement of tissue paper is not widely used, and few tissue paper lines are equipped with this type of quality control system in China. Therefore, technology for near-infrared measurement of basis weight has a great potential market in the field of tissue paper production. This article analyzes the future development trend of near-infrared light in tissue paper basis weight measurement and summarizes the difficulties in near-infrared light measurement of tissue paper basis weight.

Application: Different measurement methods suitable for measuring basis weight, moisture, and ash of various paper types are summarized in this paper. The near-infrared light measurement method is suitable for the measurement of tissue paper, but influences such as ambient temperature and humidity interference, along with onsite dust, need to be overcome.

Measurement of paper quality parameters plays an important role in the study and production of paper. It is the guarantee for controlling the quality of paper production. The main quality parameters of the paper are moisture, basis weight, ash, paper strength, etc. [1]. For these parameters, paper mills can measure almost all of them off line in laboratories under the Chinese National Standard. These offline methods have high accuracy advantages, but the detection process is complicated, the test time is long, and the paper may be damaged. To solve the shortcomings of offline measurement methods, non-destructive online measurement methods are widely used in the measurement of paper quality parameters. The commonly used non-destructive online paper measurement methods mainly include the near-infrared light method, β -ray method, X-ray method, γ -ray method, and microwave measurement method. With the development of the paper industry, more and more domestic enterprises in China have begun to pay more attention to the production requirements related to paper quality, and they have also put forward higher requirements for the paper quality control system (QCS). This paper primarily summarizes the application of some non-destructive online measurement methods for paper quality parameters. By comparing the advantages and disadvantages of various measurement methods, the trend of near-infrared light in the measure-

ment of low basis weight paper in the future is mentioned, and the problems that need to be solved are put forward.

With the advent of the era of a “low carbon economy,” the development trend of paper with low basis weight is becoming more and more prominent. However, the reduction of the paper basis weight will lead to a decrease in the opacity and stiffness of the paper, and the binding ability between the fibers will be weakened. It is important to improve paper strength by adding inorganic fillers, adding polymers in pulp, surface sizing, surface dissolution, nanofiber coating, and so on. Therefore, the detection of paper strength is also an important factor to ensure the quality of paper. Because this article mainly just introduces the online measurement method and online paper strength testing methods that are currently unavailable, papermakers still must wait for the manufacture of a complete reel to assess quality.

ONLINE MEASUREMENT METHOD FOR PAPER QUALITY PARAMETERS

Paper quality parameters include paper moisture, basis weight, ash, thickness, smoothness, paper strength, and transparency [2]. The QCS provides the possibility to realize online monitoring of paper quality parameters. At present, the international QCS system suppliers in China are Valmet, Voith, Honeywell, and ABB [3-5]. The Chinese QCS

Supplier Parameter	Valmet	Honeywell	ABB	Voith	Zhejiang Shuangyuan	Gundam Measurement and Control	Haitian Measurement and Control
Basis weight	√	√	√	√	√	√	√
Moisture	√	√	√	√	√	√	√
Ash	√	√	√	√	√	√	√
Thickness	√	√	√	√	√	√	
Transparency	√	√	√	√	√		
Smoothness	√	√	√	√	√		

I. Paper parameters measured by international and Chinese quality control system (QCS) suppliers.

Method Parameter	A	B	C
Basis weight	Infrared light	Isotope β-rays	Isotope γ-rays
Moisture	Infrared light	Microwave method	Charge transfer method
Ash	X-ray		

II. Online measurement methods for paper parameters.

system suppliers include Zhejiang Shuangyuan, Gundam, and Haitian. **Table I** shows the measurable paper parameters of international and Chinese QCS suppliers [6-8].

The two most important paper quality parameters are moisture and basis weight. Whether these two parameters meet outlined standards determines the product rating of the paper. Paper basis weight refers to the content of fiber per unit area of paper, and paper moisture refers to the moisture content per unit area of the paper [9]. **Table II** shows the commonly used online measurement methods for paper quality parameters.

Summarizing the measurement methods for various paper quality parameters shows that non-contact online measurement methods have been widely used in paper production. The yield and quality of the paper can be improved by using a high-performance QCS corresponding to the measurement method, and it is significant in terms of reducing energy and raw material consumption [10].

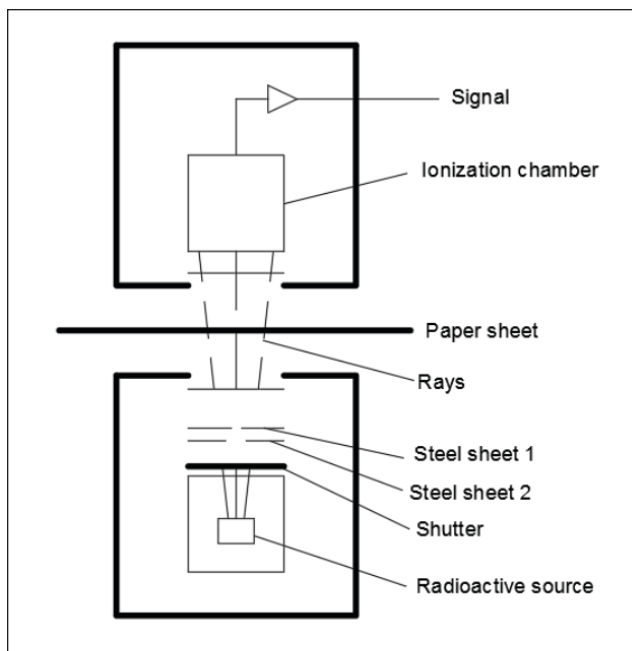
RESEARCH ON PAPER QUALITY
PARAMETER MEASUREMENT METHODS
Basis weight measurement

The basis weight of paper is used for evaluating the quality of the paper. Generally, the basis weight of the paper needs to be maintained within the tolerances specified by the standard. If the basis weight of the paper is higher than the index specified in the standard, it will lead to a waste of pulp. If the basis weight is lower than the index specified in the standard, there will be more problems in the coiling process and the rewinding conversion process of the paper. If the basis weight of the paper is not uniform,

the printing font is not clear and paper is wasted. Although the accuracy of paper basis weight detection has been improved by combining basis weight sensors with advanced controls [11], it is still challenging to use it widely in measurement of certain paper grades. The detection accuracy of the international basis weight sensor is ±0.5 g/m² in the measurement process for the basis weight range of 12~20 g/m². The measurement accuracy of the basis weight in the range of 150~1500 g/m² is expressed as a percentage. The current international basis weight sensor has a detection accuracy of ±1.0% for the basis weight in the range of 150~1500 g/m² [12].

Research on basis weight measurement in China mainly focuses on the paper basis weight range of 50~1500 g/m². Hu [13-15] studied the basis weight measurement of high-basis weight paperboard. Beta rays were chosen for paper basis weight measurement, because beta rays penetrate paper according to Bell's Law. The basis weight sensor range automatic identification fusion framework is designed to improve measurement accuracy through data fusion technology. **Figure 1** shows the working diagram of the basis weight sensor measurement.

G. Li et al. [16] put forward suggestions for the selection of the energy of the paper basis weight radioactive source. The ¹⁴⁷Pm is the best radioactive source through comparing sensitivity and statistical error, and it is usually selected for measurement of the basis weight ranging from 10 g/m² to 200 g/m². In addition, the ⁸⁵Kr radioactive source is often chosen for the basis weight range between 20~1000 g/m². **Table III** shows the β-ray source parameters currently applicable to paper measurements.



1. Schematic diagram of the basic weight sensor.

Y. Li et al. [17] proposed a pre-amplification digital method of β ionization chamber to measure the energy of β ray after penetrating the paper. The Butterworth filter was used by Zhou to process the signal in the process of paper basis weight signal processing [18]. Because temperature drift is an important factor affecting the accuracy of paper basis weight measurement, Sun et al. [19] proposed a compensation method for the temperature drift in the measurement process. When QCS technology failed to meet the detection requirements in China, Tang et al. and Wang et al. [3,4] improved the detection accuracy by researching and transforming the imported QCS system.

Some researchers have also used infrared, gamma rays, and other methods to conduct research in the measurement of paper basis weight. Li [20] developed a method to simultaneously measure the basis weight and moisture of paper with near-infrared light. This measurement method is mainly used in the basis weight range of 400~600 g/m². In addition, this method has high measurement accuracy and low comprehensive cost, and it solves the technical problem of simultaneous measurement of paper basis weight and moisture. This near-infrared measurement method also has some technical problems that need to be solved. For example, the measurement accuracy of the sensor is affected by onsite dust, and the thicker paper has poor infrared light

penetration ability.

The combined measurement method of isotope and charge method was adopted by Hou et al. to simultaneously measure paper basis weight and moisture [21]. The basis weight measurement of paper is based on the principle that the absorption of beta rays obeys the law of exponential decay. The principle of paper moisture measurement is to generate polarization charges according to the polarization of polar media in an electric field. The amount of polarized charge is measured by the method of charge transfer, and the relationship between the polarized charge and the moisture of the paper is analyzed to calculate the moisture content of the paper.

The backscattering method of low-energy γ -rays was used by Hou et al. [22] to study the measurement of paper basis weights ranging from 50 g/m² to 500 g/m². The measurement principle is based on the dependence of the interaction of the low-energy γ -rays with the paper on the atomic number. The basis weight of the paper can be determined by measuring the backscattered intensity of low-energy γ -rays proportional to the mass absorption coefficient, which can meet the requirements of measurement accuracy. The errors generated by this measurement method are mainly the unevenness of paper samples, laboratory errors, instrument errors, and so on.

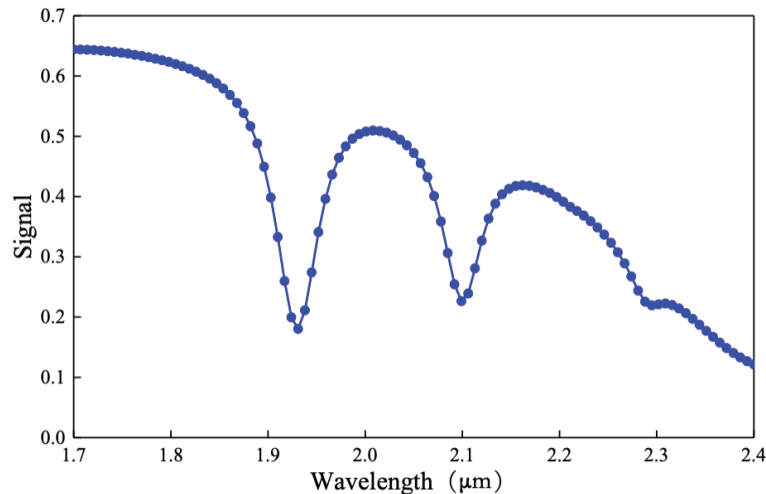
By comparing several different paper basis weight measurement methods, the most mature application in the paper basis weight measurement process is still the isotope measurement method, which can be widely used in the paper basis weight range of 10~1000 g/m². However, this method generates radiation during paper basis weight measurement. Therefore, near-infrared light measurement methods are increasingly used in the measurement of paper basis weight, especially in low basis weight paper. However, the environmental temperature, humidity, and dust factors have a major influence on the basis weight measurement of tissue paper. As a result, the near-infrared light measurement method is not widely used to measure tissue basis weight.

Moisture measurement

The moisture of the paper is another important indicator of paper quality. If the moisture content of the paper is too high, the bonding strength between the paper fibers will decrease, and if the moisture content is too low, the rigidity of the paper will increase and become brittle [11]. Therefore, ensuring stability of the moisture content of the paper

Radioactive Source	¹⁴ C	¹⁴⁷ Pm	⁸⁵ Kr	²⁰⁴ Tl	⁹⁰ Sr
Beta ray energy, MeV	0.153	0.285	0.57	0.76	2.27
Half-life, a	50.3	2.62	10.7	3.13	28.1
MeV = mega electron-volt; a = anniversary.					

II. Online measurement methods for paper parameters.



2. Typical infrared spectrum of paper.

is a basic requirement for ensuring paper quality. The real-time distribution of paper moisture can be more comprehensively reflected through online measurement of paper moisture, which is the basis of a paper quality control system. Currently, infrared and microwave methods are mainly used in the online measurement of paper moisture. The infrared method to measure paper moisture is primarily based on the principle that water molecules selectively absorb infrared light. As shown in **Fig. 2**, the measurement of moisture in paper is based on the specific absorption properties of water for near-infrared light at a wavelength of 1.94 μm, where the radiative transmission at this wavelength is compared with the intensity at a wavelength of 1.83 μm to obtain the moisture content. The 1.83 μm wavelength signal is not affected by moisture in the paper, but will be weakened by other factors and can be used as a reference signal for moisture measurement. In this process, when moisture absorbs infrared light, the paper also absorbs infrared light. The principle of microwave measurement of paper moisture is that the moisture in the paper will affect the characteristic parameters of the microwave resonant cavity, and then the moisture measurement is completed.

Infrared light measurement methods are mostly used to measure the moisture of paper with a basis weight of less than 100 g/m². Because infrared light has a poor measurement effect on thick paper, microwave measurement is often used to measure the moisture of paper with a basis weight greater than 200g/m² or even higher.

The absorption of near-infrared light by paper moisture can be expressed as:

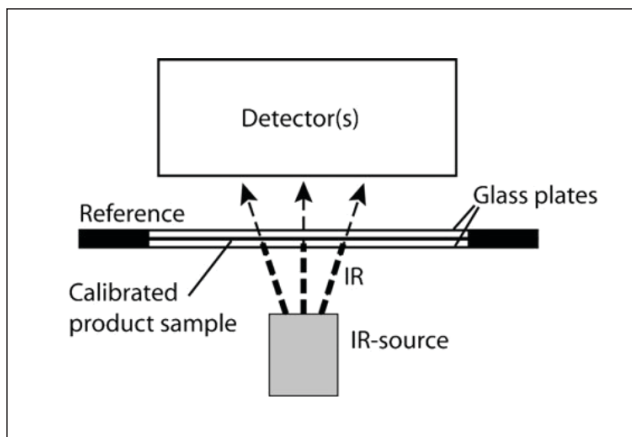
$$E_{1.94}=E_{0e}^{-KM} \quad (1)$$

where E_0 is the incident infrared energy of 1.94 μm, K is

the absorption coefficient of the paper, and M is the moisture content of the paper. The moisture in the paper sheet has four absorption bands in the infrared band, which are 1.18 μm, 1.46 μm, 1.94 μm, and 2.92 μm, respectively. At present, 1.94 μm is mainly used as the measurement wavelength, because the absorption peak of water molecules in the 1.94 μm band is relatively large, and the detection sensitivity is high.

Ye and Sun [23] proposed a new type of optical measurement system for paper moisture with high basis weight that can be used in paper moisture measurement with a basis weight less than 500 g/m². It mainly uses different lenses for modulation and retains the double-half integrating sphere structure of other moisture meters to improve the system's infrared radiation receiving efficiency. In the measurement of paper moisture with a basis weight of 150~350 g/m² and more than 450 g/m², the stable output can be obtained by using this measuring system. Dong [24] studied the method of measuring paper moisture and basis weight based on near-infrared light, which is mainly used in the measurement process for cardboard paper with a basis weight range of 0~350 g/m². According to this measurement principle, a near-infrared moisture quantitative measuring instrument that does not require a cooling structure is adopted. Multireference, multibeam measurement, and automatic compensation techniques are used in this measuring instrument, so the paper moisture measurement stability is improved. In addition, the influence of external factors, such as dust in the environment and moisture in the air, is eliminated, and the measurement accuracy is improved.

Kangasrääsiö [25] studied the integrity of the infrared light online moisture measurement system based on the multireference infrared light principle. The prepared reference is sealed between two glass plates in this measure-



3. Basic calibration of online moisture measurement based on infrared transmission.

ment system, as shown in **Fig. 3**. The thermal expansion coefficient of the glass plate is low, and the infrared light has high transparency in the glass plate. The moisture content of the reference sample ranges from 1.7% to 15%, and the paper basis weight ranges from 35 g/m² to 375 g/m². The results show that the moisture measurement error of different measurement systems can be reduced to less than 0.5% by employing a traceable method in the basic calibration process. Taking this approach improves the integrity of the online moisture measurement system and reduces the need for continuous laboratory testing.

There are some defects in the infrared light measurement system. First, thicker paper cannot be measured on line with infrared light, because the infrared light penetration ability is poor. Second, the infrared probe cannot stably work, because the paper has high impurity content and dust interference. In addition, the optical components are easily heated, which affects the service life of the sensor.

Liu [26] studied the related technology of microwave measurement of paper moisture content by comparing the problem of infrared light measurement. This measurement technology is mainly used in paper with a basis weight of 400~600 g/m² and with a moisture range of 3%~15%. Part of the energy is lost in the process of the microwave passing through the paper, and the energy loss increases as the moisture content of the paper increases. Paper moisture not only absorbs energy but also reflects microwave energy, both of which can measure moisture content. This microwave measurement system can be applied to the moisture measurement of high basis weight paper through experimental studies. This measurement technology not only has the advantages of high real-time performance, good sensitivity, strong anti-interference energy, stable measurement results, and so forth, but it also has a wide measurement range and has a relatively broad potential in the field of online moisture measurement in industrial production.

In summary, infrared light measurement is currently often used in the measurement of paper moisture in a basis

weight range of less than 200 g/m². It can be found that infrared light is widely used in the measurement of low basis weight paper. In the measurement of high basis weight paper, the microwave paper moisture measurement system is often used because of the poor penetration of infrared light in thick paper.

Ash measurement

In the processes of paper research and production, paper ash is also an important quality indicator. To improve the stability of paper quality, factors such as pulp slurry ratio, paper filler types, and changes in the properties of the filler itself cause the fluctuation of paper ash content to be reduced. In some papermaking enterprises, the ash content of the paper is appropriately increased and the amount of paper fiber is reduced. Therefore, the detection and control of paper ash have become an important link in the process of paper production and scientific research [27]. The traditional method of measuring paper ash requires a long measurement time, tedious steps, and requires burning the paper. Relevant researchers have proposed some chemical methods and improvements in traditional combustion methods to solve the shortcomings of traditional combustion methods, but these measurement methods are all contact measurements, which destroy paper filler components. The paper ash online measurement method not only improves the measurement accuracy and efficiency but also can control the production in real time and reduce the consumption of pulp. Relevant scientific research institutions and papermaking enterprises have developed the rapid detection of paper ash by ray method based on the online measurement of paper ash [28]. The main offline ray methods for the determination of paper ash are X-ray diffraction (XRD) and X-ray fluorescence (XRF) spectrometry. The principle of XRF spectroscopy (XRF) is to irradiate X-rays on paper, and each component element in the exciting paper will emit X-ray fluorescence. Also, X-ray fluorescence emitted by different elements has specific energy characteristics or wavelength characteristics. The energy and quantity of the emitted fluorescence are measured by the detection system to obtain measurement signals, and the collected signals are converted into the types and contents of various elements in the paper through the instrument software. However, the principle of XRD spectroscopy is to measure the diffraction peaks of the paper sample within a certain diffraction angle range, which is mainly used to determine the structure of the sample.

Commonly used ray methods for online measurement of paper ash content are X-ray tube measurement method, X-ray, and γ -rays method with isotope ⁵⁵Fe as the radioactive source.

Gu et al. developed a soft X-ray transmission intensity measurement method. The principle of this method is that

when the X-ray penetrates the paper, the law of attenuation of the ray intensity conforms to Bell's law [29]. Ou et al. developed a paper ash meter using the isotope ⁵⁵Fe as the X-ray radiation source [30]. The ash content of 28 different types of calcium carbonate and talc-filled paper was determined using this ash meter. The measurement results show that the error of 26 of the 28 measurement data obtained by this paper ash meter is less than 0.5%, which fully meets production requirements. Based on the selective absorption characteristics of low-energy X-rays passing through paper, Feng et al. designed an online paper ash measuring instrument using the isotope ⁵⁵Fe as a γ -ray radiation source [31]. After the field operation test, the measurement error of the measuring instrument is less than 1%, which meets the requirements of online detection of paper ash content. Using X-ray radiated from ⁵⁵Fe passing through the change of paper absorption intensity to measure ash content, Xiao used the ash sensor produced by Impact Company to detect the ash content of paper in a paper mill, and the measurement error was less than 1% [32]. Hofman proposed a method that can measure the ash content in paper products [33]. This method primarily obtains the relative content of each ash component by rapidly changing the energy level of the X-ray and comparing it with the basic physical parameters.

Guo et al. developed a paper ash online detector by using the absorption characteristics of substances to γ -rays [34]. After testing, the measurement range of paper ash content is 1%~30%, and the measurement accuracy is $\pm 0.5\%$. This measuring instrument is suitable for paper basis weights ranging from 20 g/m² to 150 g/m², and the response time is less than 50 ms.

In the field of online measurement of paper ash, X-ray measurement is currently the main method, although this method has shortcomings, including the high precision required of the measurement device, high requirements related to environment where it is used, and the small application range. However, the measurement time is short, the measurement accuracy is high, and the cost is low. According to actual production needs, the appropriate ray method is applied to measure the ash content of the paper, which can improve the production efficiency of the enterprise.

DEVELOPMENT TRENDS IN INFRARED LIGHT FOR MEASURING TISSUE QUALITY

With growth in population and rapid development of the economy, the consumption of paper and cardboard has increased in China. From 2011 to 2020, the average annual growth rate of production was 1.41% in China, and the average annual growth rate of consumption was 2.17% [35].

New, efficient, and environmentally-friendly technical equipment is used in papermaking enterprises. It will inevitably save energy and reduce consumption, improve the environment, and improve economic efficiency [36,37]. Measurements of parameters such as basis weight and moisture are usually taken from paper rolls due to the lower speed of previous paper machines. According to the traditional method for paper parameter measurement, the whole measurement process is quite cumbersome, and the obtained results vary widely due to the large uncertainty of manual operation [38]. If the basis weight and moisture content of the paper are to be measured in real time and comprehensively, it is necessary to realize the online detection of paper quality parameters. Only in this way can field operators and quality inspectors keep abreast of the production status of the paper machine and solve problems in a timely manner. **Table IV** shows common measurement methods for paper basis weight and moisture in different basis weight ranges.

The basis weight of tissue paper is mainly in the range of 10~20 g/m². In this range, infrared light and ¹⁴⁷Pm radioactive source are often used to measure the basis weight online. The ¹⁴⁷Pm radioactive source is used in the process of making tissue because of its good sensitivity, but it is limited because of the radioactive measurement method.

Voith has developed a nonradioactive sensor (the LSC type TecoSens sensor) specifically for tissue machines that simultaneously measures the moisture content and fiber content of the tissue paper. It uses an infrared moisture sensor that measures infrared absorption at four wavelengths and has a baseline correction function. The use of such a sensor minimizes the influence of environmental factors or paper color on the measurements [39]. Paper fiber weight and moisture can be simultaneously measured with the Valmet IQ Fiber sensor developed by Valmet. This sensor has replaced the traditional nuclear basis weight

Method \ BW, g/m²	Tissue Paper 10-20	Glossy Paper 18-40	Writing Paper 45-80	Coated Paper 80-400	Corrugated Paper 120-200	White Cardboard 230-450	Packaging Paper 250-1000
Infrared light	√	√	√	√	√		
Microwave				√	√	√	√
¹⁴⁷ Pm	√	√					
⁸⁶ Kr			√	√	√	√	√

IV. Commonly used online measurement methods for paper in different basis weight (BW) ranges.



4. Onsite dust accumulation.

analyzer by improving the infrared technology, and it has been successfully installed in more than 140 tissue machines worldwide [40]. The high-efficiency infrared fiber quality sensor (HPIR-FW) introduced by ABB can measure paper fiber quality, paper web moisture, and paper web temperature at the same time while using only one infrared instrument. The sensor avoids numerous complicated procedures because no radioisotopes are used for the measurements [41].

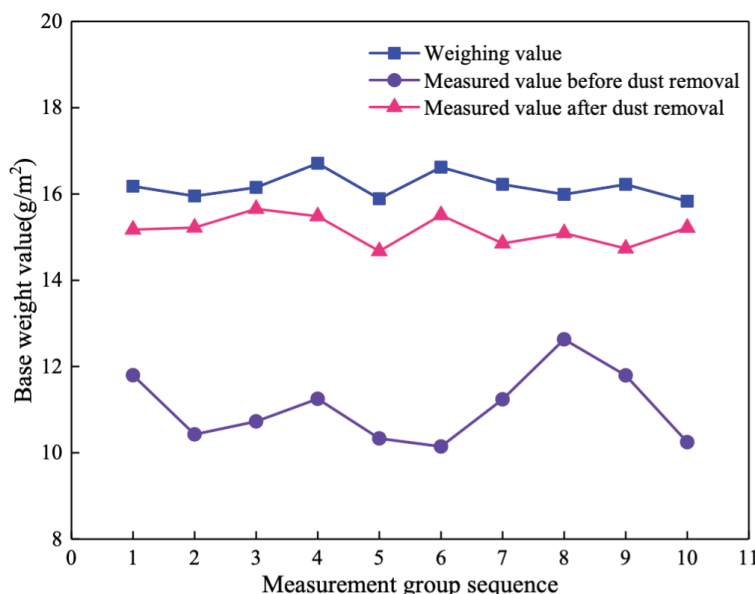
The OUMDS-III intelligent near-infrared paper basis weight and moisture measuring instrument was developed by Liyuan Science and Technology in Xi'an, Shaanxi Province, China. This sensor is suitable for online dynamic continuous measurement of the basis weight and moisture of various types of paper in paper mills and paper processing lines. Also, it can realize automatic control of paper basis weight and moisture by connecting with other control equipment. The measurement range of paper basis

weight is 10~400 g/m², and the measurement range of paper moisture is 0%~20%.

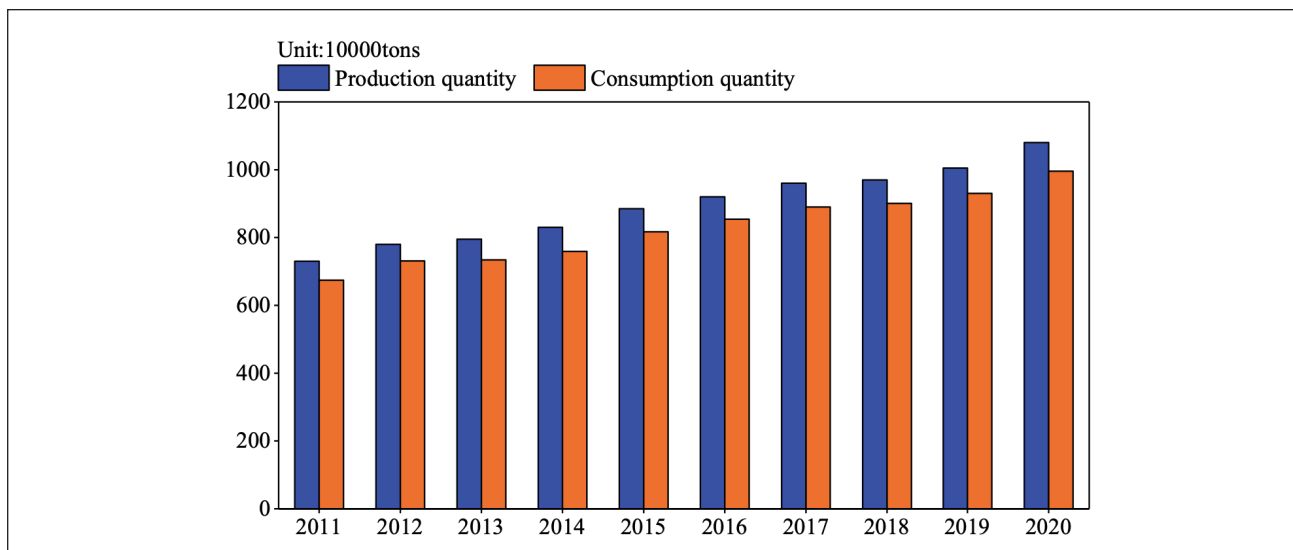
Infrared light also has many issues in the measurement of tissue paper. The dust disturbance at the production site, the ambient temperature and humidity, the speed of the paper machine, and the transmission effect of the sensor are all factors that affect the measurement results of near-infrared light. The dust at the production site is mainly composed of paper wool from the shedding of fine fibers during the wrinkling process of paper and dust in the air. **Figure 4** shows the accumulation of dust on the scanning frame.

Figure 5 shows the results of measuring the basis weight of 16 g/m² paper by near-infrared light before and after removing dust from the sensor platform. Future research in the use of near-infrared light for measuring tissue basis weight will focus on how to minimize the dust impacts on infrared light transmission and the impact of ambient temperature and humidity on the measurement process.

As shown in **Fig. 6**, the production of tissue paper in 2020 was 10.8 million tons in China, an increase of 7.46% over the previous year; the consumption was 9.96 million tons, an increase of 7.10% over the previous year. From 2011 to 2020, the average annual growth rate of production was 4.45%, and the average annual growth rate of consumption was 4.43% [35]. In the next ten years, it is expected that the consumption of tissue paper will reach about 50 million tons around the world, and the possibility of meeting this prediction is very high [42]. With the increasing production and consumption of tissue, paper-making enterprises have greater demand for paper basis weight and moisture measurement equipment. Infrared



5. Basis weight value of near-infrared light measurement before and after dust removal.



6. Production and consumption of tissue in China from 2011 to 2020.

light online measurement of paper parameters shows good development potential in the field of tissue.

The application of QCS in tissue paper production is relatively simple. However, because the manufacture of tissue has its own characteristics, the QCS system cannot relax the standards in terms of operation speed, control performance, and environmental characteristics [43]. To further enhance the performance of the QCS system, the control of the transverse basis weight of the paper machine has been improved by optimizing the scanning measurement method [44]. To meet the needs of different production scales, products covering various production scales from small to large will be formed in terms of system scale and structure [45,46]. The QCS system has been improved into a networked, integrated, and intelligent system, which is of great strategic significance to papermaking enterprises [47,48].

CONCLUSION

Quality parameter measurement plays a pivotal role as part of the paper production process. Online measurement of paper quality parameters will continue to be the trend in tissue paper production in the future, and there will be significant improvements. In this research article, the application of near-infrared, β -ray, X-ray, γ -rays, and microwave measurement methods in the field of paper parameter measurement are compared. The measurement of the basis weight of paper in the range of 40~200 g/m² is better with ^{85}Kr , and the measurement of the basis weight of paper in the range of 10~40 g/m² is better with ^{147}Pm . However, these two methods are not economical for measuring basis weight and cause radiation contamination. Infrared light measurement is also widely used in the measurement of low basis weight paper. However, the temperature, humidity, and field dust in the production environment have a major influence on the results in the measurement of tissue paper by near-infrared light. Mea-

surement accuracy can be significantly improved by overcoming these interference factors. Near-infrared light measurement of paper basis weight will be widely used in tissue paper production.

Future research can be devoted to the improvement of factors such as onsite dust interference, sensor light-emitting temperature, and ambient temperature and humidity during infrared light measurement. This will provide a better technical guarantee for papermaking enterprises to improve process accuracy and paper quality. It is also an inevitable requirement for enterprises to enhance market competition and to improve production efficiency and economic benefits. **TJ**

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ABOUT THE AUTHORS

This research primarily focuses on the measurement of tissue paper basis weight with near-infrared (NIR) light and the difficulties in this measurement process. The most challenging aspect of this study was the summary analysis of paper parameter measurement methods, including the sorting out of some measurement methods. The problems with obtaining NIR measurement of tissue paper basis weight in China were addressed through careful analysis.

We found that while paper basis weight measurement methods are well established, tissue basis weight measurement needs further development. We also discovered that the measurement error of NIR light in the actual production of tissue paper is reduced by compensating for the algorithm of ambient temperature and humidity, as well as designing a mechanical dust-removing device for a scanning frame.

Our main focus for the next step in this study is how to reduce the influence of temperature, humidity, and dust on NIR light measurement, primarily concentrating on the measurement algorithm and mechanical design.

Hu is associate professor and Ma is a Master's student in the College of Mechanical and Electrical Engineering, Shaanxi University of Science and Technology, Xi'an, Shaanxi Province, China. Email Ma at majin2@sust.edu.cn.



Hu



Ma

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