Study on High Precision Fabric Density Measuring Instrument and Measuring Method Based on Moire Fringe

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Abstract. With the continuous development of science and the continuous progress and reform of fabric knitting technology, all kinds of fabrics continue to appear. Linear density is one of the most important physical and geometric characteristics of knitted fabrics, which affects the physical and mechanical properties, feel and style of textiles, and is one of the important bases for fabric design and manufacturing process parameters. In this paper, a device and method is developed, which is not affected by the width and density of fabric lines, and can accurately measure the density of fabric. The invention puts forward a method of measuring fabric density from a new point of view. Using the phenomenon of moire fringes, the fabric density of the fabric to be measured is calculated by measuring the angle. The device has the advantages of simple structure, low production cost, and is not affected by the width and density of cloth lines. It can measure fabrics with high line density or wide lines, and has the advantages of high precision and convenient operation. And the gratings with different grating constants can be selected according to the characteristics of the fabric, which has a very wide range of application.

Keywords: Fabric braiding technology, geometric properties, linear density, determination of fabric density, grating.

1. Introduction

Linear density measurement is an important item in fabric testing. However, there are many problems in the methods of measuring fabric density in the market. As far as the density measurement of textile fabric is concerned, the manual measurement method is usually used, which has the disadvantages of slow speed, low efficiency, high labor intensity and high labor cost [1]. The recognition and count of automatic density measurement method is poor, and its application range is relatively narrow. In the instrument measurement method, the cloth density ruler, which relies on the moire fringes formed by sector radiation gratings and straight gratings as the principle [2], is generally only used to measure fabrics such as fishing nets and screen windows whose line density is relatively negligible compared with the gap between their lines. It is impossible to measure fabrics with higher line density or wider lines, and, due to the limitation of design principle, in some measurement areas [3]. The accuracy of the cloth that can be measured is relatively low. This study can greatly improve the fabric detection efficiency, change the existing manual measurement methods, and provide a new idea for further research in the future.
2. Principle and model of moire fringe

2.1. Principle of moire
At present, there are several views on the causes of moire fringes, including the shading and shading principle (the area where the upper grating obscures the light transmission gap below the cloth, and the bright stripe formed by the intersection of the grating and the cloth) [4]. The interference diffraction principle of light, another is that the moire fringes are caused by the difference between the cloth and the grating, through Fourier transform. The line corresponding to the intersection of the lowest spatial frequency formed by the two is the moire fringe. In this paper, the principle of shading shadow is used to explain the formation of moire fringes [5].

2.2. Model of moire
This paper mainly discusses the moire fringes formed by grating and cloth, for different fabrics, the width of the line cannot be ignored, so the experiment is carried out with the grating whose line width cannot be ignored, as shown

![Fig. 1 Bright and dark moire fringes](image1)
![Fig. 2 Magnification model](image2)

The light and dark stripes in Figure 1 are Moire's stripes, while Figure 2 is a magnified model based on the phenomenon on the left. It is obvious that the dark stripes in Figure 1 are the areas surrounded by the black border in Figure 2.

As shown in figure 1, sloping black lines for homemade grating, the lower is the fabric used in the experiment, assuming not pervious to light part of the grating width for p, pervious to light part is q, the cloth is not pervious to light part a, pervious to light part for b, cloth line and the Angle theta of grating line, moire fringe and cloth line of alpha Angle, so according to the geometric relationship between solving the following equation:

![Fig. 3 Parameter diagram](image3)

According to previously assumed geometry model, first extracted a parallelogram, shown in figure 3, according to the cloth and grating parameters and the given Angle, can find out about h1 equation:
Similarly, according to a parallelogram another extract solution on \( h_2 \) equation:

\[
h_2 = \frac{q}{\sin \theta} + \frac{a}{\tan \theta}
\]  

(2)

am

Then, according to the triangle relationship marked in Fig. 5, the included Angle \( \alpha \) can be solved:

\[
\tan (90 - \alpha) = \frac{q + p}{\sin \theta} \frac{a + b}{\tan \theta}
\]  

(3)

Then, according to the triangle relationship marked in Fig. 5, the included Angle \( \alpha \) can be solved:

Cloth density = 1 mm/ \((A + B)\). (Unit: root /mm)

3. The cause of Moire's fringe visually
In order to explain the visual effect of moire fringe formation simply and clearly, this paper uses a pencil lead as a simple grating to do an experiment and explain the principle of shading.

Below (left) is the use of pencil lead and linen as experimental material experiments, right on the basis of the parameters of the left, and without considering the cloth and the line width of grating, simulated images, said to form the actual area of dark stripes shadow parts: sloping line is adjacent to the two vertical line’s cross part after the split, connect the rectangular area, it forms the eyes of moire fringe.
The slanted gratings are separated by vertical lines. According to the phenomenon in the left figure of Figure 6, the areas where Moire's stripes appear are artificially connected into a rectangle represented by the shadow in the right figure, which contains all the areas where the dark stripes are formed. In this area if there is no black grating, any difference between the region and other regions, when the add grating, it is not pervious to light within the rectangle area compared to other area is larger, so it forms reflects the brightness difference to the human eye, and also showed that a kind of light and shade of moire fringe, this is the moire fringe formation on the vision. When the grating constant is constant, that is, the value of $P + Q$ is constant, the width of the gate line is increased, and the proportion of the area of the light-resistant area in the rectangle is expanded, and the visual effect of the dark stripes reflected will be more obvious.

Since cloth parameters and grating constants affect the formation of Moire fringe, the author classifies the Moire fringe generated by different parameters. The first is the clearly visible Moire fringe that can be formed, such as the Moire fringe used in the derivation of Equation (3) above, which I defined as continuous Moire fringe, as shown in Figure 7:

When other control conditions remain unchanged, as the grating parameters gradually increase, the phenomenon of Moire fringe gradually weakens and appears as shown in Fig. 8:
When other control conditions remain unchanged, as the grating parameters gradually increase, the phenomenon of Moire fringe gradually weakens and appears as shown in Fig. 8:

\[ p + q = 2(a + b) \cos \theta \]  

(4)

This case, dark stripes in the rectangular area are independent of each other, separated, not form a continuous moire fringe, resulting in the phenomenon is not clear, so that it does not apply to equation (3), this paper will this state of moire fringe is defined as the continuity of moire fringe, and between the continuity and discontinuity moire-fringe moire fringe there must be a critical state, and according to the geometric method is easy to get the equation of state, when considering the grating and cloth line width equation is as follows.

4. Influence of different parameters on the measurement of fabric density

In order to further explore the practicability of equation (3) in the actual measurement and the influence of different experimental conditions on the accuracy of data, this paper will start from the Angle between the cloth and the grating, the intensity of the light source illuminating the cloth, the parameters of the grating and the cloth with different parameters.

4.1. The Angle between the cloth and the grating

When the cloth and grating are constant and the \( \theta \) size is changed, the width of Moire fringe will be different. According to the geometric relationship, when the cloth is placed parallel to the main grating lines, the width of Moire fringe formed is the maximum, while when \( \theta \) gradually increases, the width of Moire fringe will gradually decrease until the human eye cannot distinguish it. When the grating is changed, the maximum Moire fringe width will also change. Therefore, in conclusion, the influence of Angle \( \theta \) on the measurement of cloth density lies in the influence on the width of Moire fringe. However, when the width of Moire fringe is too large, the edge of Moire fringe will present an irregular state of curve due to the influence of the parallelism of cloth lines, resulting in errors in the measurement of Angle \( \alpha \), as shown in the figure below:
The influence of Angle on data measurement is further explored. When the grating and cloth are kept constant, θ is changed, which are 2.682°, 6.560°, 12.680°, 18.263° and 23.509° respectively. The cloth is linen, A + B =1.5mm, as shown in the right picture below.

Fig. 9 Irregular moire fringes

Fig. 10 Parameter comparison

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Fig. 11 Contrast result
The following is the experimental data of the above five placement angles:

**Tab. 1 Angles and relative error**

| Angle     | 2.682 | 6.560 | 12.680 | 18.263 | 23.509 |
|-----------|-------|-------|--------|--------|--------|
| Relative error | 1.00  | 0.20  | 0.53   | 0.43   | 0.13   |

![Relative Error Graph]

**Fig. 12 The relative error**

The horizontal axis is the magnitude of $\theta$, and the vertical axis is the relative error between the measured fabric density and the actual fabric density. It can be seen from the image that, with the increase of the Angle, the width of Moire fringe gradually decreases, and the influence of the fabric nonparallelism gradually weakens, and the relative error measured shows a downward trend on the whole.

4.2. *The light source*

Under different intensity of light source, the actual effect of Moire fringe is not the same, and the measured experimental data are also not the same, which is mainly caused by the contrast difference between the bright and dark Moire fringe. When the intensity of the light source increases, the brightness of the bright part of the light increases especially significantly compared with the brightness of the dark streak, and there will be a contrast improvement, making the phenomenon of Moire fringe observed by human eyes more obvious.

Using the different levels of brightness produced by the screen as a luminance adjustment device, explore the different effects brought by the light source. 1, 2, 3, 4, 5 and 6 are the six levels of screen brightness marked in the figure below. The experimental data are shown in the figure below:

**Tab. 2 Angles and relative error**

| Light intensity level | 1  | 2  | 3  | 4  | 5  | 6  |
|-----------------------|----|----|----|----|----|----|
| Relative error/%      | 6.733 | 2.067 | 0.800 | 0.867 | 1.400 | 0.133 |
Fig. 13 Light source and relative error

From the point of the shape of the curve, with the increase of light brightness, the contrast of light and dark lines gradually increases, the human eye can observe the moire pattern is more obvious, is reflected in the data, with the increase of the intensity of light source, can the accuracy of measured fabric density be also gradually increased, the relative error is a downward trend.

4.3. The light source

To explore grating parameters, influence on fabric measurement, a simple experiment was carried out, the author uses the ink production gradually smaller grating and the arrangement of a series of gap in each of the two-cartridge placed at the center of a ballpoint pen, according to this method to proceed slowly, on the premise of guarantee the high precision, making as much as possible of pencil lead configuration. As shown in the figure below:

Fig. 14 Result of parameter change

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5. Conclusion

With the continuous development of fabric weaving technology, the linear density characteristic has become an important parameter affecting the characteristics of textiles. In this paper, the methods of measuring fabric density in the market are discussed and analyzed, and a fabric measurement method based on moire fringes is proposed. The effects of different parameters such as the angle between cloth and grating, light source and grating parameters on cloth measurement are studied, and the accuracy of the measurement method is obtained.
References

[1] Yu Yuelin, Gu Xuefeng, Wu Leyuan, Chen Weilai. Research on square meter quality of yarn padded fabric and construction of prediction model [J/OL]. Modern Textile Technology:1-7 [2021-03-26]. http://kns.cnki.net/kcms/detail/33.1249.TS.20210125.1149.004.html.

[2] Xun Limei. Improvement of testing method for linear density of woven fabric removed yarn [J]. Wool Textile Science and Technology, 2020548 (12): 73-77.

[3] Li Dangjuan, Wang Jiachao, Wang Jia, Kangya, Yan Jing. The influence of grating parameters on the image quality of moire fringe animation [J]. Journal of Xi'an University of Technology, 20200.40 (04): 373-377.

[4] Ding Shanting, Cheng Zhuang, Zhai Zhongsheng, Li Jinsong, Huang Jiaojie, Lu Qinghua, Wang Xuan. A method for locating the center of moire fringes of non-diffracted light [J]. Applied Optics, 2019. 40 (04): 652-657.

[5] Song Ying. Research on static and dynamic phase locking of interference fringes in holographic grating exposure system [D]. Graduate School of Chinese Academy of Sciences (Changchun Institute of Optics and Precision Machinery and Physics), 2014.