REAL TIME THICKNESS MEASUREMENT OF A MOVING WIRE

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ABSTRACT

LASER diffraction is one of the simple and precise techniques for the real time thickness measurement of a moving wire. It is desirable that the thickness of the wire or fiber during the production time should be maintained to a uniform thickness along the entire draw length. When we illuminate a wire with a LASER, the diffraction pattern of the wire is produced. From the diffraction pattern of the wire its thickness can be calculated. The principle of the method used is discussed in detail, and its experimental verification of its performance is reported. The theoretical calculation of the thickness of the wire using its formula is also presented. Using this method, a fiber diameter, thickness measurement is possible with an error of ±5μm from its actual thickness value. ±5 tolerance is permissible with the detector resolution and the environmental conditions made into consideration.

Keywords:Diffraction, Diffraction Pattern, Beam Profiler, Babinet Principle

I. INTRODUCTION

It is desirable that the thickness of the wire should be in uniform along the entire draw length for various applications. A thickness measurement is inevitable in order to control the wire drawing machine during the production time. In most of the industries the diameter measurement is performed in order to improve the quality of product. Several approaches have been taken in order to measure the thickness of moving fine wires. With previous methods are mechanical in nature. So that the moving wire will come in contact with the machine. The difficulty is that the contact itself causes distortions in the wire. Another approach involves the use of light for the thickness calculation. Electronic and optical microscopy provide the thickness calculation of tiny targets, but the difficulty is that the wire has to be brought to a laboratory like environment.

Different methods were examined for the thickness calculation of the wire optically. Several methods were designed based on LASER scanning, diffraction and the interferometer. Here the same diffraction principle is used for the thickness calculation including small drift calculation with slight changes. [1] Matching the observed diffraction pattern with the already calculated diffraction pattern. It is a simple method for analyzing the thickness of the wire by observing the changes happening on the horizontal scale of the pattern. By Babinet Principle, the diffraction pattern of a wire is same as that of a slit of the same width. Thickness calculation of wire in the millimeter range is shown in [2]. Thickness measurement of wire is made with the help of the laser, optical fiber and microprocessor. The method can even apply for large as well as medium thickness wires. It shows an increase in the error value as the thickness of the wire gets increased. Here a maximum error value of 0.24mm from the actual thickness value is exhibited. The diameter measurement along with a laser scanner for detecting the large spatial drifts occurring in the wire is shown in [3]. Thickness calculation is done for the wire with a drift of ±5mm from the actual position. In [4] it made a diffraction model for the diameter measurement of a cylindrical wire and an interferometric calibration is done to validate the result. In [5] diameter variations are measured with a diameter resolution by 0.02% for wires ranging from 25 to 300µm.Reflective novel scanning heterodyne optical interferometer used to get the thickness variation in sub micron level is shown in [6].

In the proposed design, the thickness calculation of the fiber in the micrometer range, suffering from random vibration is made. It is able to observe small drifts due to vibrations during production. Here the distance calculation is possible at an accuracy of 0.01mm. It is an easy and cost effective method to calculate the thickness of the moving wire during the production time. And the same phenomenon diffraction can be used for both the thickness as well as distance calculation. Because of that, with the usage of same infrastructure, both observations are possible optically.

II. EXPERIMENT

Fig 1 shows the general setup for both thickness as well as the movement measurement of the wire for the industrial purpose. It can be applied in industries, so that the thickness variations in wires can be monitored during the production time itself. Here the collimated beam of light coming from the LASER is split by the beam splitter for the thickness measurement and the distance measurement purpose. A beam splitter is an optical device which can split an incident light beam (e.g. A laser beam) into two which have the same optical power. One of the beams falls directly on the moving wire and it produces the diffraction pattern of that wire on the beam profiler. From that diffraction pattern we will get the thickness of the moving wire . Another beam will fall on a mirror setup and the beam is spread by using a diverging lens. The diverged beam makes a diffraction pattern on the beam profiler, which is used for the movement calculation of the wire .

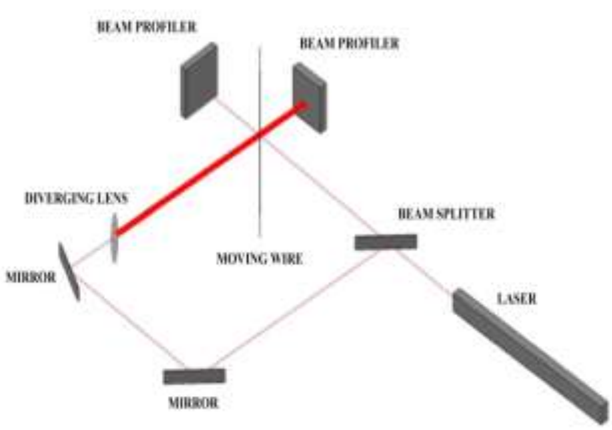

Fig.1.Thickness and distance measurement setup

A thin moving wire was illuminated by a He-Ne Laser of wavelength 632.8nm. The diffraction pattern of that particular wire is obtained on the screen. The horizontal scale of the pattern varies when the thickness of the moving wire undergoes any variations. And the diffraction pattern of the wire get shifted with the vibration in the wire. The thickness of the wire is measured by determining the spacing between central maxima and 1st minima and the distance between the wire and detector is measured by observing the shift in the pattern.

As the wire is a moving one, the diffraction pattern is also affected by its movement.. But it is difficult to trace the parameter that causes changes in the diffraction pattern. Horizontal and the vertical movement of the moving wire can be obtained by observing the shift occurring in the diffraction pattern. The horizontal movement can be detected from the same setup used for the thickness measurement. For the vertical movement measurement an additional setup should be needed perpendicular to the previous setup. Then the whole setup will provide the thickness of a moving wire. Distance measurement can be made possible at an accuracy of 0.01mm.

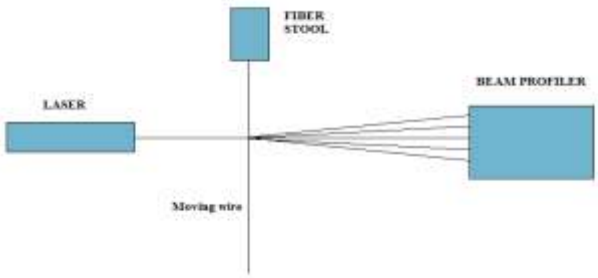

Fig a

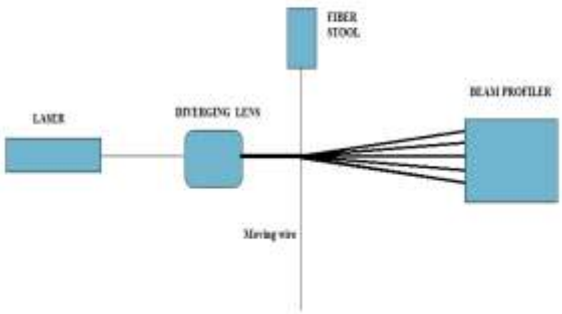

Fig b

Fig 2. Real time thickness measurement of a moving wire. (a)Thickness measurement (b) Movement detection

III. RESULT AND DISCUSSION

As a part of the verification of the method, a manual calculation was done. A thin fiber of diameter 125μm is illuminated by a helium–neon LASER with the radiation wavelength of 632.8nm. A laser beam that falls on the fiber setup creates a diffraction pattern. It is observed on a Slim photodiode power sensor placed perpendicular to the laser beam. From the dual channel optical power meter the maximum intensity point and the minimum intensity point are noted. From the Vernier caliper the distance between these two points were noted. The distance between the power sensor and the fiber setup is noted, and thickness is calculated using the formula:

t= $(\lambda * D)$ /y. --------- (1)

Below (fig 3) shows the plot of thickness versus trials. Here trials were made with the slim Photodiode power sensor and dual channel optical power meter and the corresponding thickness was calculated using the formula (1). Several trials were made, and the graph is plotted. This method is chosen as a part to verify the method and the formula chosen for the thickness measurement. Here the plot is almost constant shows that we got the thickness value nearer to the actual value for all the trials.

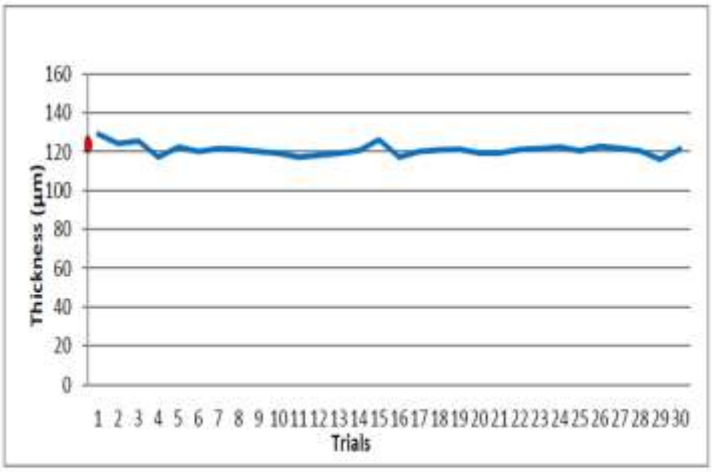

Fig 3. Method verification for the fiber with thickness 125µm

Distance measurement uses the principle of a shift in the diffraction pattern due to the horizontal movement of the wire with respect to the beam profiler. Distance measurement was done by observing the shifts in the pattern and is able to detect even 0.01mm drift in the wire.(Fig 4)

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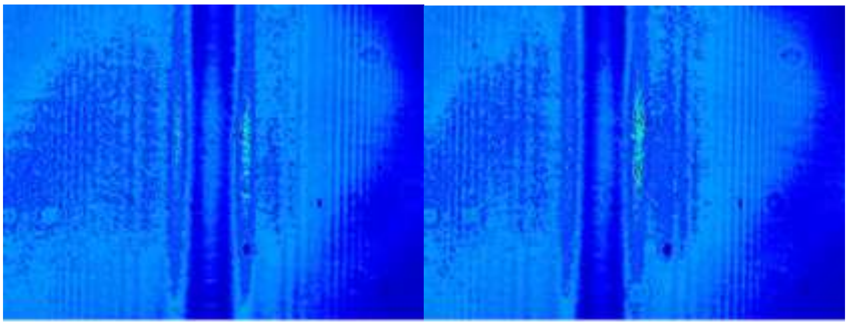

Fig 4. Shift in the diffraction pattern

From the beam profiler output (Fig 5) diffraction of the moving wire is obtained. With digital image processing, the pattern is processed, the distance between the central maxima and 1st minima is obtained and thickness of the wire is calculated.

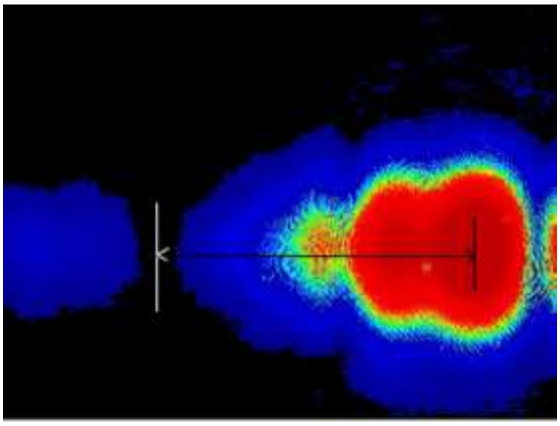

Fig 5. Beam profile

If the 0.01mm drift in the wire is not considered appreciably, it will create an error of 0.00322µm in the thickness calculation. Below graph (Fig 6) shows the shift in the wire when the wire undergoes a drift of 0.01mm from a point to the other. Fig 7 shows the graph showing the variation in the observed thickness from the actual thickness value (i.e. 125µm) of the wire. It shows a variation of ±5µm from the actual thickness value of the fiber.

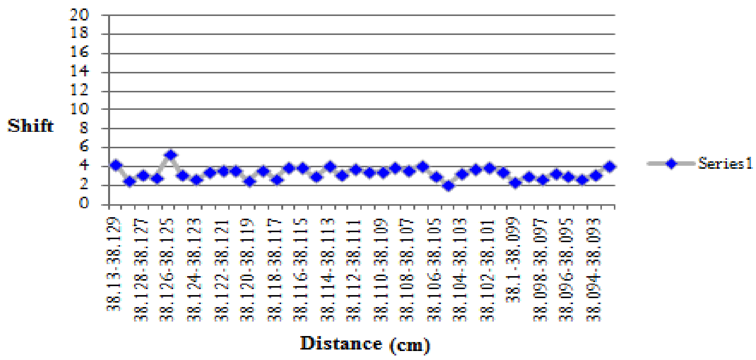

Fig 6. Shift in the diffraction pattern

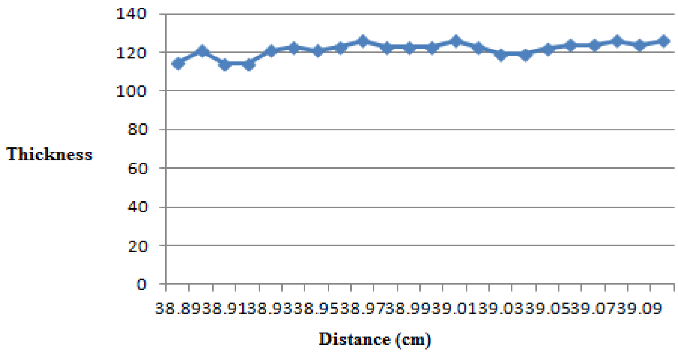

Fig 7. Thickness of the wire at different distances

Reading error is one of the major factors that affect the precision of the readings. Atmospheric temperature fluctuations, vibrations, background lights are the other factors affecting the diffraction pattern. These types of fluctuations are included in random errors. The variations while taking the data during the whole day indicates the changes that are happening in the diffraction due to atmospheric changes. Because of that the place, date, time and the specification of the components should be noted while doing such experiments.

IV. CONCLUSION

Real time thickness measurement of a moving wire is done using the diffraction principle. Variation in the single wire/fiber will make disastrous impact in the finished product. Variation in a single fiber may be negligible, but it will affect the finished product if these fibers combined to a single strand. To validate the method chosen a thickness calculation is made manually with slim photodiode power sensor and dual channel optical power meter. An experimental setup is made to calculate the thickness of the wire drifting vertically and horizontally. Separate experimental setup was made to calculate the thickness as well as the small drifts in the wire. Both of them provide thickness values near to the measured thickness value of the wire.

Most optical thickness measurements today provide the thickness value in the millimeter range. The methods consider only the large spatial drifts. But the proposed thickness measurement using beam profiler provides a reading nearer to the actual thickness value with an error of only ±5μm. The proposed movement detection method measures drift as low as 0.01mm in wires.

It is a simple and accurate method to measure the thickness of the wire/fiber during the production time, so that its drawing can be regulated. Employing a high resolution CCD camera can provide a better result. With this the thickness measurement using the diffraction principle can be improved to a greater extent.

V. ACKNOWLEDGMENT

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