Microwire measurement device

Valerian DOROGAN
Technical University of Moldova
dorogan_lme@yahoo.com

Eugeniu MUNTEANU
Technical University of Moldova
eugeniumunteanu@gmail.com.com

Sergiu ZAPOROJAN
Technical University of Moldova
zaporojan_s@yahoo.com

Sergiu TINCOVAN
Technical University of Moldova
s_tincovan@mail.ru

Vitalie SECRIERU
Technical University of Moldova
primcast@mail.com

Dumitru GORGAN
Technical University of Moldova
gorgandima@gmail.com

***Abstract*—A new method is proposed for analyzing and measuring the microwire core diameter and glass coat thickness. Two light beams in visible spectrum are used for measurement of core diameter. The analysis and measurement of glass coat thickness is provided by using two ultraviolet light sources. The method neglects the diffraction effects of light.**

***Index Terms* — microwire, light frame, differential amplifier.**

I. Introduction

The requirements to the equipment of microwire production grow with the increase of production volume. A full automation of microwire casting is expected in this concern. Microwire manufacturing should also provide higher quality and production volume. A way of improving the production quality is the assurance of continuous information and knowledge about microwire parameters on casting.

The most common techniques for measuring microwire geometrical parameters are provided by post manufactory measurements (by using microscope or devices for measuring the magnetic parameters of microwires). These techniques are incompatible within automated production of microwires. A MR meter is usually used for core diameter measurement on casting [6], which allows the operator to monitor the diameter of microwire and control the casting process. Unfortunately, its typical accuracy is of a 5 to 10% order, within quite narrow limits. It is too difficult to improve and expand the capabilities of the MR meter. This is why the data provided by this meter cannot be used for a large range of diameters.

An automated casting process based on the measured MR is only possible and acceptable within some limits (approximatively, in a 4 to 30 micrometers range). Besides this, there is not much information about the thickness of microwire glass coat on casting – a very important parameter for some microwire application.

Other methods of measuring thin wires are based on scattering and diffraction effects of a laser beam [4]. These methods are quite precise and accurate and, at the same time, exigent to environmental conditions and wire vibrations during measurement process.

The method described in this paper is a good challenge to provide quick measurements of microwire parameters and can be easily implemented into an automated process of microwires manufacturing.

II. Light Absorbtion

Light absorption effects represent the basis of the described method. The visible light absorbed by the microwire must be analyzed for measuring the microwire core diameter. The purpose of the method is to obtain a lower or even absent light absorption of the glass coat compared to the core.

A lower light transmittance at short wavelengths should be considered for measuring the thickness of glass coat.

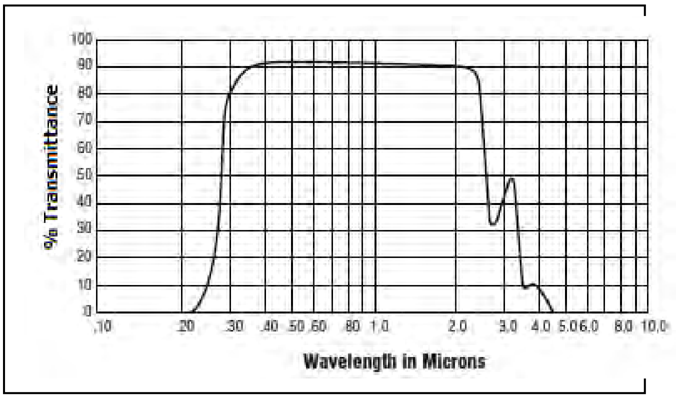

Fig. 1. Light absorbtion of Pyrex-like glass.

Figure 1 shows the approximated transmission quotient of light for Pyrex like glass. A higher transmittance quotient results into a lower light absorption in glass. It is evident from the figure, that the absorption effects are quite weak for the visible light up to the mid-range of infrared spectrum (0.4-2.5 µm). In this context, one can suppose that light attenuation is smaller for the microwire coat.

The absorption grows rapidly for ultraviolet light (400-280 nm) and the glass becomes opaque for the deep ultraviolet light range (UVC 100-280nm).

The microwire absorption value of ultraviolet light depends also on scattering, refraction and diffraction effects. The influence of refraction and diffraction effects can be reduced depending on light measurement techniques and post processing of the measured light intensity.

The absorption value of ultraviolet light in the microwire glass coat is higher than the absorption value of visible light at the same light intensity. The key principle of the described method is an average absorption value of the microwire for different wavelengths of the light beam.

III. Device Compoents for Measurements

Special optical parts with following features were designed for providing the described measurement techniques:

- High reliability and low maintenance requirements for optical parts.
- Easy implementation of microwire automated production.
- High tolerance to electrical and light noise.
- Low values of light refraction and diffraction effects.
- Low light absorption provided by the optical parts of the device.

The features mentioned above are satisfied using different techniques: design and parameters of the device, design of electrical schemes and post measuring analysis and calculations.

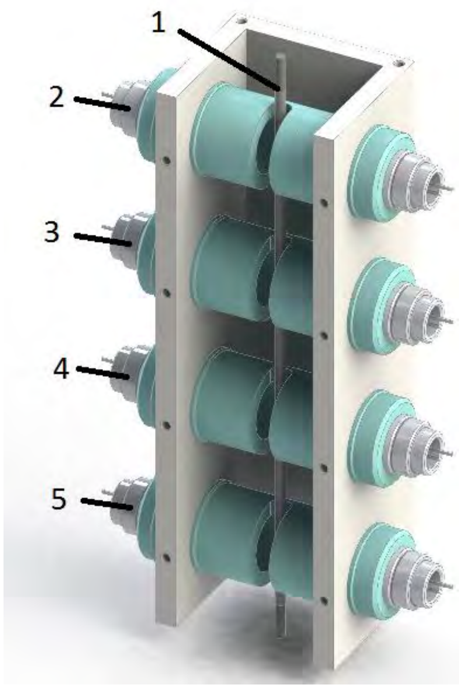

Fig. 2. Main view of collimation system

A. Optical overall

Figure 2 shows the prototype of optical parts used in the described microwire measurement device with the following components:

1) Microwire. The measured microwire crosses over special gapes of collimation groups for assuring convenient device usage in plants with automated casting of microwires.

2,3) Collimation groups λ_1. These groups are designed to operate with visible light laser beam. The signal obtained from the output is used for calculating the microwire core diameter. Calculation results are used for estimating the glass coat thickness.

4,5) Collimation groups λ_2. Light emitters used in these groups provide an ultraviolet C diapasone (UVC) radiation to obtain higher light absorbtion of inside the microwire glass coat. The optical parts (lens, optical windows, etc) of these collimation groups must provide high transparency for UV light .

B. Collimation group

The collimation groups were designed according to the requirements enforced by the proposed method of measurement.

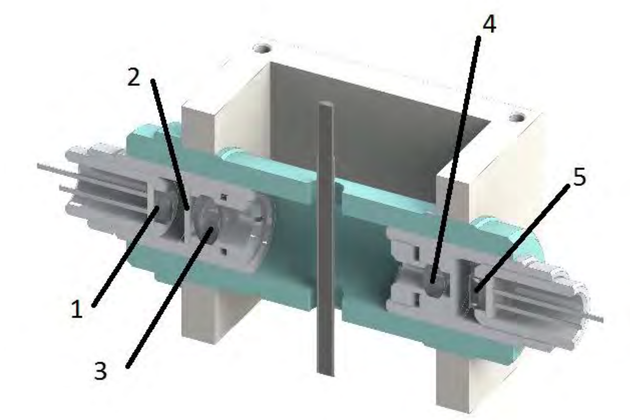

Fig. 3. Collimation group.

Figure 3 shows the sectional view of the collimation group with the following parts:

1) Light beam emiter (laser or LED): The light wavelength is λ_1.

2) Light frame: can be mechanical or optical. The shape of the frame can be rectangular or eliptical.

3) Collimating lens: can be double-convex or plano-convex. It is preferably to use plano-convex lens for better collimation results, esspecialy when a LED is used as light source.

4) Focusing lens: can also be double-convex or plano-convex. The spectral transparency of glass must be considered for the focusing and collimatting lens for assuring maximum transparency of light at used wavelengths.

5) Light sensor: photodiode or photo transistor sensitive to the wavelength of light source.

IV. Measurement Method

The measurement method is based on light attenuation of the microwire. LEDs or lasers can be uses as light source with a certain wavelength range. The light sources must provide a range of light absorption values depending on the core diameter and the thickness of glass coat. Absorption values are obtained using scattering, diffraction and shadow effects of the light beam.

The device was designed to highlight scattering and shadow effects of light beam and the shape and position of the device components assure low values of light absorption and side effects, including diffraction effects and light noise attenuation.

A. Shape of the light beam

The shape of light beam represents a start point for measuring microwire parameters.

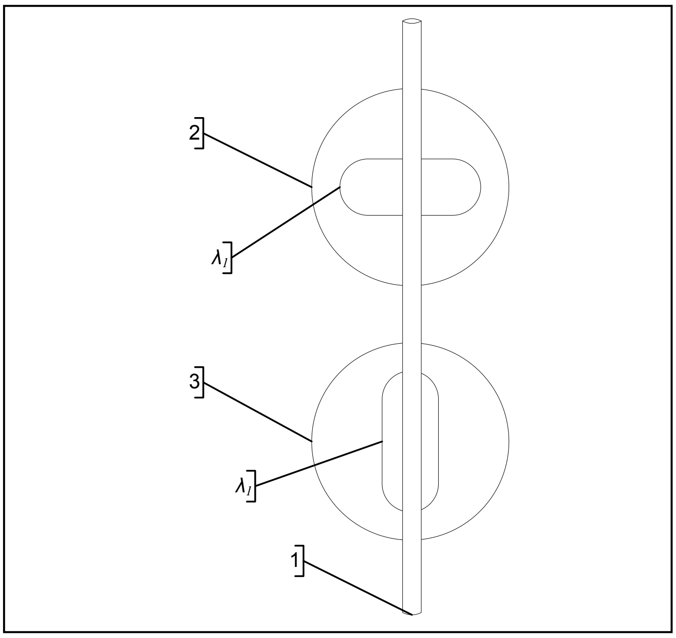

Fig. 4. Shape of the light beam and the microwire position.

The shape of the light beam must be rectangular or elliptical (oval) according to the measurement method. Figure 4 shows an example of the shape of the light beam. The microwire flow through two collimation groups is shown in the figure (component 1). In the figure are also shown the light frames (components 2 and 3) of collimation groups and the way the shaped light beams with identical wavelengths (in reference to λ_1 symbol) intersects the microwire.

The described measurement method proposes that the microwire has to intersect the light beams in a way that the light attenuation and scattering would reach maximum values. The axes of the light beam shape must be perpendicular to each other.

A pair of collimation groups has to be identical, which means that the wavelength of light emitters, the emitted light intensity, the light shape, the collimation quality, the light focusing, and the spectral sensitivity of photodetectors must have identical parameters.

B. Signal measurement and diameter calculation

A rectangular frame used for beam sharpening will provide the following surface of the light beam:

$$S_{\lambda 1} = H * W, \qquad (1)$$

where H – frame length, W – frame width;

The photodetectors would provide the same value of output signal if there are no barriers for light beams and the collimating groups have identical parameters.

$$I_{\lambda 11} = I_{\lambda 12}\,, \qquad (2)$$

where $I_{\lambda 11}$ and $I_{\lambda 11}$ are the output signal values for the collimating group 1 and 2, respectively (Fig. 5). The collimating groups use light emitters with the basic wavelength λ_1.

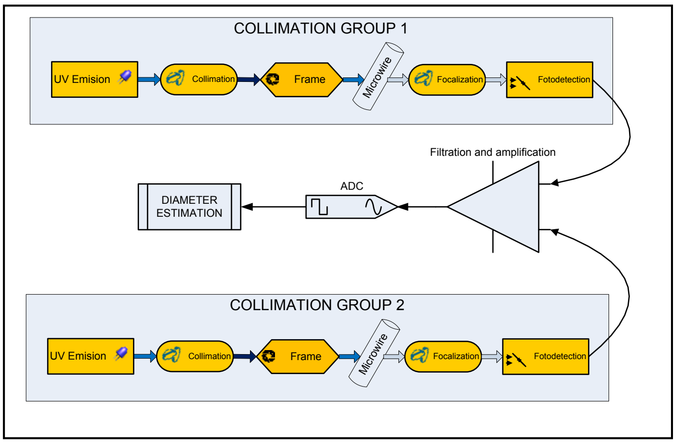

Fig. 5. Signal measurement

The light beam sharpener for collimation group 1 is represented in Figure 4 by the component 2. The output signal value is:

$$I_{\lambda 11} = k * \Phi_{\lambda 1} * [(H*W) - (H*d)], \qquad (3)$$

where k – constant, which represents the conversion rate of light energy into electricity, d – microwire diameter. The signal output value can also be represented as:

$$I_{\lambda 11} = K_{\lambda 1} * H * [W - d]. \qquad (4)$$

The conversion rate for light flow is $K_{\lambda 1}$ for the designed collimation group and is the same for the “collimation group 2”. The light sharpener of the “collimation group 2” is represented by the component 3 in Figure 4. The output signal value for the “collimation group 2” is:

$$I_{\lambda 12} = K_{\lambda 1} * W * [H - d]. \qquad (5)$$

Once the collimation groups have the same conversion rate into electricity they can proportion between (4) and (5):

$$I_{\lambda 12} / (W * [H - d]\ ) = I_{\lambda 11} / (H * [W - d]). \qquad (6)$$

The expression (6) can be written as:

$$I_{\lambda 12} / (W * [H - d]\ ) = I_{\lambda 11} / (H * [W - d]). \qquad (7)$$

To assure a better signal to noise rate (useful or useless signal) the sharpening frame must be as thin as possible, comparable with microwire diameter. The height of the frame is much bigger than the width and microwire diameter. In this case:

$$[H - d] \approx H. \qquad (8)$$

The microwire diameter can be calculated using the following expression after substituting (8) in (7):

$$d = W * [1 - I_{\lambda 11} / I_{\lambda 12}]. \qquad (9)$$

The output signal values $I_{\lambda 11}$ and $I_{\lambda 11}$ are preamplified. The signals are applied to the inputs of a differential amplifier after preamplification. The output signal of the differential amplifier represents the amplified rate ($I_{\lambda 11}$ / $I_{\lambda 12}$). Once converted to a digital value, the signal value can be inserted into expression (9) for estimating the microwire diameter.

The diameter estimation will represent a value closer to microwire core diameter for the collimation groups with light sources of λ_1=*550nm* wavelength. The light sources of the collimation groups with λ_1=*260nm* wavelength provide a signal for calculating the diameter of the entire microwire, including the glass coat.

V. Conclusion

Light scattering is an effect that has a major impact on measurement accuracy. The measurement of the entire microwire diameter, including glass coat, is essentially affected by the scattering effect. This is a reason for additional care to be taken when selecting components for UV collimation groups.

The device described in this paper is under a prototype design. A lot of issues have been faced during measurement tests and certain improvements have been developed after processing experimental data.

A quite thin frame sharpener is used to increase the useful signal to noise rate. Measurement failures during microwire vibration represent a drawback of this solution. In this case, the described method is not applicable for measurements made using an automated microwire casting plant. The spinning of the collimation group by a small angle (about 10^0) could serve as a work around. Both collimation groups were turned into a position so that its light beam would cover the microwire vibration amplitude.

These angular and position improvements lead to a review of the diameter calculation formula (9). The change of calculation formula, side effects of the light beam attenuation changes the estimation method of microwire diameter by using empirical values. Using these methods it is possible to obtain higher accuracy for a certain range of microwire core diameters and different alloys, glass coat thicknesses and types.

References

[1] M. E. Fedorov, "Optical laser diffraction transducer for measuring single-wire electric cable eccentricity", IOP Conference Series: Materials Science and Engineering,Volume 81, conference 1, 2015.

[2] Juan Carlos Martinez-Anton; Ibrahim Serroukh; Eusebio Bernabeu, "Laser diffraction wire diameter measurements: correction of diffraction models by interferometric calibration", SPIE 3824, Optical Measurement Systems for Industrial Inspection, (21 September 1999).

[3] Soraya A. Khodier, "Measurement of Wire Diameter by Optical Diffraction", Optics & Laser Technology, ELSEVIER, · February 2004, Pages 63–67.

[4] Soraya A. Khodier, "Measurement of Wire Diameter by Optical Diffraction", SPRINGER, Journal of Optics, March 2003, Volume 32, p. 19-25 .

[5] Tang, W., Zhou, Y., & Zhang, J. (1999) "Improvement on theoretical model for thin-wire and slot measurement by optical diffraction". Meas Sci Technology, 10, 119-123.

[6] S. Zaporojan, C. Plotnic, I. Calmicov, V. Larin, "A Knowledge-Based Approach for Microwire Casting Plant Control". Knowledge-Based Intelligent System Advancements: System and Cybernetic Approaches, p.419-432, Information Science Reference, Hershey, New York (2010)

[7] De Kai-Erik Peiponen, Risto Myllylä, Alexander V. Priesshev, Optical Measurement Techniques: Innovations for Industry and the Life Sciences. Springer Series in Optical Sciences 136 (2009).

[8] E. Fred Schubert, Light-Emitting Diodes, second edition, Cambridge University Press (2006).

[9] Didier Decoster, Joseph Harari, Optoelectronic Sensors, ISTE Ltd and John Wiley & Sons Inc. (2009).