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NON-CONTACTLESS MEASUREMENT OF ALPACA HAIR DIAMETER

The article presents the results of a study of the diameter of alpaca hair using the laser technology. The dependence of the hair diameter change on such fac-tors as the distance of the hair from the screen, the position of the diffraction fringes was analyzed. The values of these factors caused the hair diameter to fluctuate. Based on the experiments, it was shown that by using of laser light diffraction, it is possible to measure very thin alpaca hair.

Keywords: hair diameter, light diffraction, alpaca

1. INTRODUCTION

The demand for luxury materials in modern times is undoubtedly becoming more and more common. Buyers have increasing requirements regarding the quality of the product, and are therefore they are looking for new solutions that will meet their needs. Currently, sheep's wool dominates the entire world market, while the rest of the fibers, such as alpaca (Fig.1), lama or angora, are special fibers. Alpaca wool (Fig.2) has become a very luxurious commodity on a global scale.

Among other things, it is distinguished by its incredible softness and very thin fiber, which is up to three times more durable than sheep's wool. Such a collection of textile products, which will find a place in the closet, are sure to last for several years, as the fibers do not deform or tear. In addition, it has thermal insulation properties, it is definitely much warmer than sheep's wool and at the same time lighter.

Due to its low lanolin content, it is not very susceptible to staining, and it is also resistant to dust mites and most recommended for allergy sufferers, as it is non-sensitizing. The quality of alpaca hair depends mainly on the type of animal as they vary in thickness. Thin fibers are the most desirable because they are definitely softer and highly valued, and therefore breeders select alpacas to improve the quality of their products. [1,2].

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Fig. 1. Alpaca

The science that deals with hair is trichology. Trichology is a branch of medicine that only developed only in the mid-19th century. The origin of the word trichology goes back to the Peloponnese peninsula, which was part of historic Laconia. The name itself is derived from the Greek "trikhos" and is the equivalent of the term "hair" in Polish. The innovators of this branch are considered to be the British. One of them was Professor Wheeler, who undertook research to find the factor that resulted hair loss, and proposed various treatments.

Another significant date in trichology is the founding of the Trichology Institute, which took place in 1902. The experience gained there in 1928 gave rise to the world's first specialized institution – The Scalp and Hair Hospital, based in London, which dealt with the treatment of conditions related to the scalp and skin loss. Another instytution with a worldwide reach is the Association o Trichologists (IAT). It was founded in the 1970s in California. Polish precursors of trichology include Professor Wojciech Kostanecki and Dr Doman Michałowski, who published their books in the 1970s, e.g. Diseases of the Hair – a book by Professor Wojciech Kostanecki [3].

Alpaca wool, obtaining of which is now becoming increasingly popular, should be characterized in terms of hair diameter . In the literature, one can find the measurement of the hair diameter using a scanning microscope (SEM) and the Laser -Scan instrument [4]

For this purpose, we use laser technology using light diffraction. The optical method is contactless, remote and non-inertial.

The wavelength of radiation coming from the laser, which illuminates the fiber and, as a result, undergoes the phenomenon of diffraction, will serve as the standard of length in the measuring system. As a result, on the screen we get a distribution of diffraction strations obtained on the screen, which gives an image identical to that of a long and narrow slit. A camera was used to record the diffraction image.

Fig. 2. Alpaca wool: a) red, b) light, c) brown

2. MEASURING SYSTEM

The measuring system (Fig. 3) consists of a Ne-Ne laser, a mask for cutting with a zero-order fringe, a screen on which diffraction fringes (Fig.4) could be observed, and a camera for recording the fringes.

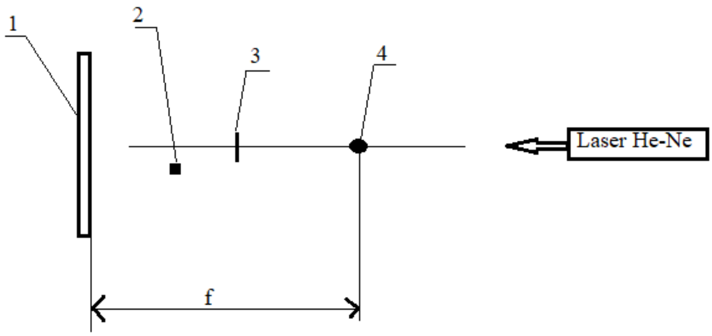

Fig. 3. Measurement for the determination of hair diameter,
f – distance of hair from the screen, 1 – screen, 2 – camera,
3 – mask, 4 – hair

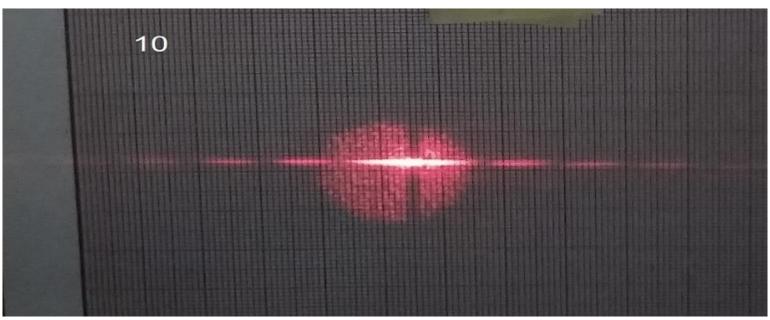

Fig. 4. Distribution of diffraction fringes for light hair

3. HAIR DIAMETER CALCULATIONS

According to the Babinet's principle, the non-transparent and transparent areas are complementary areas, therefore the obtained diffraction fringes distributions are identical. Using the formula [5,6]:

$$I(x) = A^2 d^2 \frac{sin^2\left(\frac{x\pi d}{\lambda f}\right)}{\left(\frac{x\pi d}{\lambda f}\right)^2} \tag{1}$$

where: I(x) – light intensity, d – diameter of the hair, λ – wavelength, f – the distance of the hair from the screen, x – coordinate along the diffraction image on the screen.

Considering: $\lim_{x \to 0} \frac{sin^2\left(\frac{\pi dx}{\lambda f}\right)}{\left(\frac{x\pi d}{\lambda f}\right)^2} = 1$ for x = 0 we obtain $I(x) = I_0$

Minima occur for given values x:

$\frac{\pi dx}{\lambda f} = k\pi \rightarrow x = \frac{k\lambda f}{d}$, where k – the row of the fringe

Adjusting rasters to any distribution of fringes is possible because of fixed distances between the fringes. Using the position of the dark stripes, we calculate the hair diameter using the formula:

$$d = \frac{k\lambda f}{x} \tag{2}$$

For example, the diameter (Tab.1)of a light hair was calculated:

$$d = \frac{1 \cdot 6{,}328 \cdot 10^{-7} \cdot 0{,}6}{0{,}012}$$

$$d = 0{,}0316\ [mm]$$

Table 1. Results of calculations of the diameters of individual hairs

Hair	Raster [mm]	x [m]	f [m]	d [mm]
Red	12	0,024	0,955	0,0504 ± 0,0051
Light	12	0,024	0,6	0,0316 ± 0,0032
Brown	8	0,016	0,675	0,0534 ± 0,0081

Type B standard uncertainty :

$\Delta f = 0{,}003m$

$$u(f) = \frac{\Delta f}{\sqrt{3}}$$

$$u(f) = \frac{0{,}003}{\sqrt{3}} = 0{,}00174\ [m]$$

$\Delta x = 0{,}001m$

$$u(x) = \frac{\Delta x}{\sqrt{3}}$$

$$u(x) = \frac{1}{\sqrt{3}} = 0{,}58\ [mm] = 0{,}00058\ [m]$$

Extended uncertainty:

$$U(f) = k \cdot u(f)$$

Dla k = 2:

$$U(f) = 2 \cdot 0{,}00173 = 0{,}0035\ [m]$$

Dla x:

$$U(x) = k \cdot u(x)$$

Dla k = 2:

$$U(x) = 2 \cdot 0{,}00057735 = 0{,}0012\ [m]$$

The uncertainty of the result u (d) was calculated for the measurement of the diameter of a light hair:

$$u(d) = \sqrt{\left(\frac{\partial d}{\partial x} \cdot u(x)\right)^2 + \left(\frac{\partial d}{\partial f} \cdot u(f)\right)^2} = \sqrt{\left(-\frac{\lambda f}{x^2} \cdot u(x)\right)^2 + \left(\frac{\lambda}{x} \cdot u(f)\right)^2} \tag{3}$$

$$u(d) = \sqrt{\left(-\frac{0{,}633 \cdot 10^{-6} \cdot 0{,}6}{0{,}012^2} \cdot 0{,}0012\right)^2 + \left(\frac{0{,}633 \cdot 10^{-6}}{0{,}012} \cdot 0{,}0035\right)^2} \approx 0{,}0032\ [mm]$$

Suri hair is approximately 30-35 microns in diameter. For comparison: human hair is typically has a diameter of 40-120 microns in, cashmere goat hair is 16-17 microns, and the thickness of a sheet of paper is about 100 microns [7].

4. CONCLUSION

The measuring system using light diffraction makes it possible to determine of the diameter of a thin hair. The measurement is remote, non-contact and non-inertial. In this study the diameter of an alpaca hair was measured. The diameter of a human hair is about 0.07 mm larger than the diameter of an alpaca hair.

The measuring system is suitable for finding very fine hair, including alpaca hair. The smaller the diameter of alpaca hair, the higher the price.

The quality of alpaca wool depends on the hair diameter. The best quality wool is characterized by a very small hair diameter. The smallest hair diameter was obtained by an alpaca with a light colored wool, it is: 0.032 [mm].

The uncertainty of the hair diameter consists of the uncertainty of matching the raster to the distribution of diffraction fringes and the uncertainty of the distance of the hair from the screen.

The uncertainty in determining the hair diameter is most influenced by the uncertainty in determining the position of the diffraction fringes. It is recommended to use a line camera to record the distribution of diffraction fringes.

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