Hough Transform for the Calculation of Twist Angle of Aramid Torsion

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ABSTRACT

Aramid yarns are widely used for various technical applications. For example, they are used for creation of a magnetosensitive element of the torsion magnetometer, which is a part of the geophysical complex GI-MTS-1 (SPbF IZMIRAN). Such element is made of three microfilaments of aramid yarn. Study of such physical-mechanical characteristics of yarns as tensile, shear and torsion moduli, is necessary for improvement torsion magnetometer. This paper describes the preparatory phase of experimental study of yarn twist angle variation during tensile test. It includes equipment description, in particular, description of the scheme of video capture, and developed computer vision algorithm for determining an aramid torsion slope angles. Proposed scheme of video capture includes high-speed camera and allows precise focusing due to two-coordinate platform and avoiding of optical distortions. A special computer vision algorithm, which based on the Hough transform, was developed. This algorithm was tested on torsion images obtained with digital microscope. The algorithm works with different real yarns regardless of their color and twist type.

Keywords

Segmentation, Hough Transform, image recognition, microfilament aramid yarns, Helically Anisotropic Rod, torsion bar, tensile test, high-speed camera.

1. INTRODUCTION

Aramid yarns are widely used for various technical applications. For example, they are used for creation of a magnetosensitive element of the torsion magnetometer, which is a part of the geophysical complex GI-MTS-1 (SPbF IZMIRAN) [KSPLZ10a]. Such element is made of three microfilaments of aramid yarn, which have diameter of 0.016 mm, using special device [KSPL10a], [PKN14a]. Study of such physical-mechanical characteristics of yarns as tensile, shear and torsion moduli, is necessary for improvement torsion magnetometer.

The magnetosensitive element is a torsion bar, which has helical anisotropy elastic properties and can be modeled as Helically Anisotropic Rod (HAR).

Authors of the current paper propose an experimental analytical method of evaluating physical and mechanical characteristics of the helical lines of HAR, videlicet, to fix lines slope angles versus axis of HAR during tensile test [Per12a]–[MMSS84a]. It is planned to use a high speed camera for getting yarn images during tensile. These images will be processed by computer vision algorithm to determine required slope angle.

There are several methods for determining a yarn twist angle (a slope angle of a coil). Cybulska [Cyb99a] used an algorithm based on least squares. Ozkaya et al. [OAJ2010a] used spatial and frequency domain methods combination. Kofnov and Shlyakhtenko [KS2014a] proposed to use twodimensional discrete fast Fourier transform. In the current paper authors propose an alternative method based on the Hough transform.

This paper describes the preparatory phase of experimental study of yarn twist angle variation during tensile test. It includes equipment description, in particular, description of the scheme of video capture and description of the developed computer vision algorithm for determining aramid torsion slope angles.

2. OBJECT OF RESEARCH

An object of the current research is the elastic torsion suspension (Fig. 1), which is used to create magnet indicator rotation axis. This suspension is a «braid» of three strands (one thread in each strand). The envelope of torsion bar cross-section is the ellipse with longer axis of 0.046 mm and shorter axis of 0.033 mm. The total length is 100 mm. The density of braiding is 7 knots/mm.

An optical study of the elastic torsion structure was carried out in the laboratory of electron microscope and physical and technological researches of the Peter the Great St.Petersburg Polytechnic University.

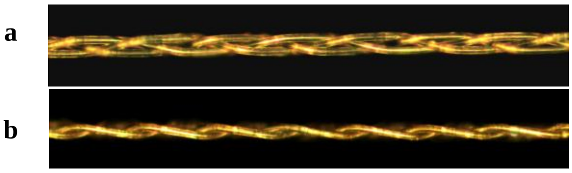

Figure 1. Photos of braided torsion bars: Two orthogonal projection: top view (a), side view (b)

3. EXPERIMENTAL EQUIPMENT

Experimental determination of physical and mechanical characteristics of torsion suspensions will be performed at the department of Mechatronics of ITMO University. Tensile tests will be carried out with the test machine AGS500NX SHIMADZU (SHIMADZU CORPORATION, Japan). Taking into account small size of samples special grips were designed. These grips are the bollard grips with a bollard diameter less than 20 mm. Tensile test data processing are produced with the special software «TRAPEZIUM LITE X» (SHIMADZU CORPORATION, Japan).

To get images during the tensile the camera CamRecord CR450x3 Optronis (Optronis GmbH, German) will be used. This camera allows taking pictures at speeds up to 10 000 frames per second. Taking into account geometric parameters of the object of the research special scheme of video capture was designed (Fig. 2). This scheme includes: 1 – high-speed camera Optronis CR450x3; 2 – controlled positioning platform for focusing during microphotography; 3 – camera bellows; 4 – Nikon F to M42 mount adaptor; 5 – mechanical RMS–M42 adapter; 6 – microscope lens [PK14a].

This scheme allows precise focusing due to two-coordinate platform and avoiding of optical distortions. Insignificant disadvantages of this scheme are absence of the diaphragm regulation, it is possible to solve with sufficient lighting; unwieldiness of the scheme, but it is not currently important in the laboratory.

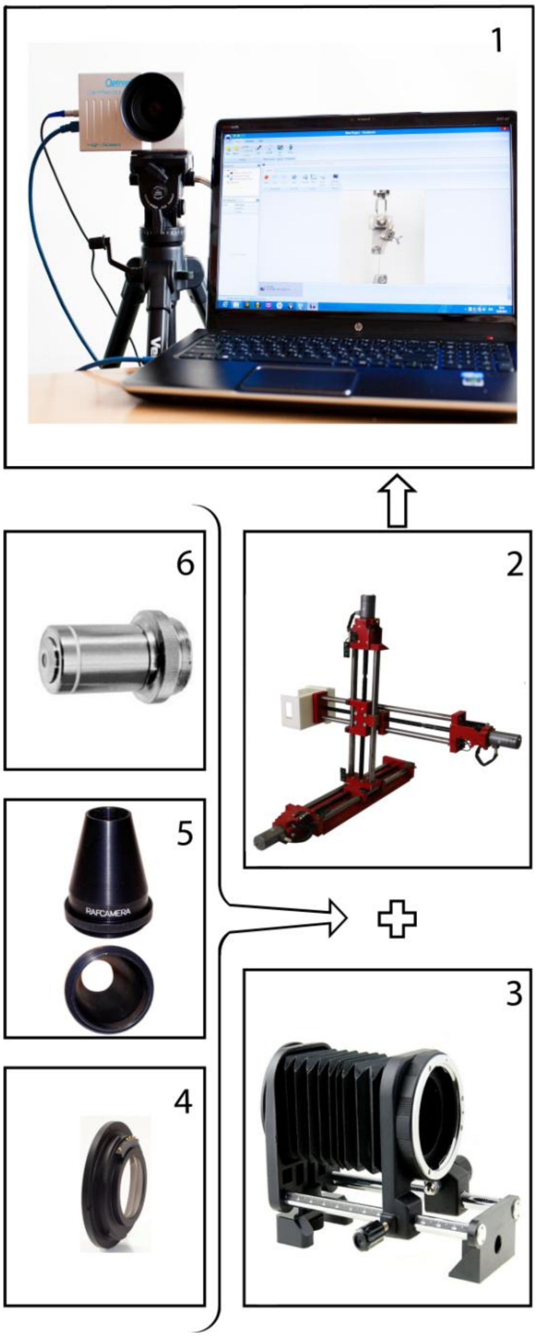

Figure 2. Schematic structure of the video capture organization

4. DEVELOPED ALGORITHM

A special computer vision algorithm was developed to determine aramid torsion slope angles. The main concept of this algorithm is based on image segmentation and application of the Hough transform. Image segmentation allowed identifying torsion edges. The Hough transform was used to detect lines that correspond to coils edges.

The program algorithm has the following steps:

1) Image loading and preparation;
2) Determination of torsion axis;
3) Edge detection;
4) Determination of coils vectors;
5) Calculation of angle of slope of coils;
6) Calculation of average angle
7) Output the results.

During the first stage image loading and its conversation to “double” format were conducted. After that the area with better lighting was selected. The purpose of these operations is the simplifying and changing a representation to make future analyze.

According to various researches [BL12a], [SC12a] Canny edge detection algorithm has the best performance especially for images without noise. This method was used in the current work. A threshold was selected using Otsu’s method. Therefore the image with torsion edges was obtained as a result of above operations.

An aramid torsion slope angle is determined as the inverse cosine of inner product of coils and torsion axe vectors. To find torsion axe a distance between torsion edges was analyzed, viz. a center of this distance was determined. Most of center points had the same horizontal coordinate describe torsion axe. To find coils vectors and a twist type the Hough transform [Hou62a] was used. After that torsion slope angle and average angle was determined.

Developed algorithm was tested for torsion images obtained with digital microscope. Figure 3 demonstrates the algorithm execution for images with 25X and 50X magnification. Also this algorithm was tested for images of staple yarn (Fig. 3c).

5. FUTURE WORK

Future work consists of testing developed algorithm on images obtained with high-speed camera during tensile test. After that it is planned to determine such elastic constants as modulus of elasticity (E_1), shear modulus (G_1), and Poisson ratio (ν_1) using following equations of HAR theory:

$$\left.\begin{aligned}\alpha_{11} &= G_1(9\phi_1 + 18\phi_2) - \frac{1}{2-\nu_1} 9\phi_2 E_1 + E_1 - 3\phi_1 E_1 \\ \alpha_{12} &= -G_1(3\phi_1 + 12\phi_2) + \frac{1}{2-\nu_1} 6\phi_2 E_1 + \phi_1 E_1 \\ \alpha_{22} &= G_1\left(\frac{tg^2\alpha_0}{2} + 8\phi_2\right) - \frac{1}{2-\nu_1} 4\phi_2 E_1\end{aligned}\right\}$$

Where $\phi_1 = 1 - 2ctg^2\alpha_0 \ln\sec\alpha_0$;

$\phi_2 = \frac{1}{2}\sin^2\alpha_0 - 1 + 2ctg^2\alpha_0 \ln\sec\alpha_0$;

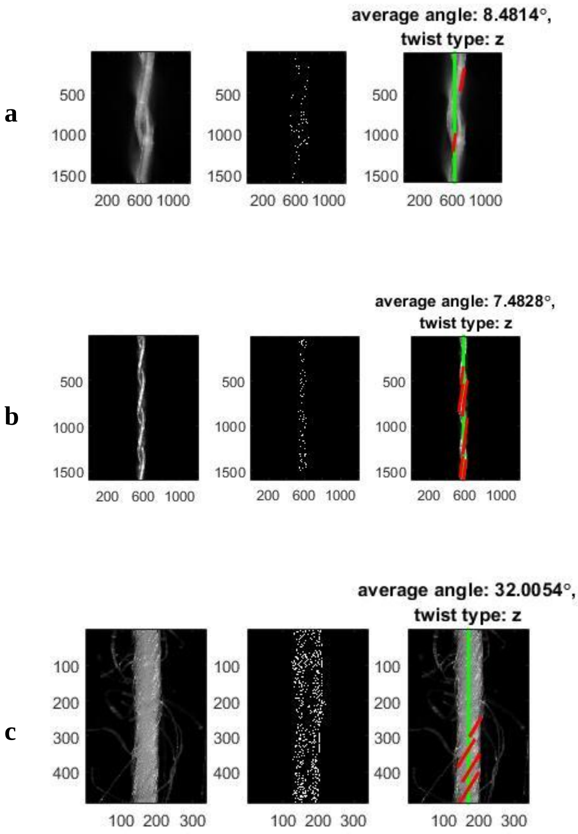

Figure 3. Algorithm execution: for torsion images with 50X(a) and 25X(b) magnification; for images of staple yarn (c)

α_0 – the determined angle of incline of the helical lines.

Within each interval find the minimum value of the functional for given values ν_1:

$$F(\bar{x}) = \left[E_1 \cdot \bar{g}_1 + G_1 \cdot \bar{g}_2\right]^2 \longrightarrow \min$$

Finally, calculate the required data using optimization methods [Per12a]–[MMSS84a].

6. CONCLUSION

This paper describes the preparatory phase of analytical experimental study of aramid yarn elastic constants. It includes equipment description, in particular, description of the scheme of video capture, and developed computer vision algorithm for determining an aramid torsion slope angles. Proposed scheme of video capture allows precise focusing due to two-coordinate platform and avoiding of optical distortions. A special computer vision algorithm was developed to determine an aramid torsion slope angles. This algorithm works with different real yarns regardless of their color and twist type.

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