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COMPUTER-AIDED EVALUATION OF MIGRATION DEGREE OF HETEROGENIC FIBERS AT CROSS-SECTION OF YARN

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There are known methods of evaluating migration suggested by J. Hamilton, M. Coplan, W. Klein, L. Rudolph, W. Onions, R. Toshnival, P. Townend, M. Kirshner. Mathematical analysis of these methods under condition of absolute random distribution of fibers across section has been carried out by authors of this paper. The analysis revealed that the examined indices have one or more drawbacks: impossibility to evaluate the statistical accuracy of the migration index, low level of statistical accuracy, bias of estimator.

Possibility to use computers lifts restrictions (related to labour intensity of computations) on designing migration index. The suggested method is based on section view of yarn, which becomes available for computer analysis with the aid of scanner. Operator marks with a mouse click the center positions of fibers of the 1st component, then of the 2nd component, etc. Computer processing of fiber center coordinates proceeds in 2 stages:

1. Reduction of yarn section to a circle (approximately) without distortion of the sequence order of heterogenic fibers in tangent direction, which also enables to evaluate in future the tangental unevenness.

2. Calculation of migration index and its statistical accuracy.

Several variants of determining migration index have been developed. Selection of the best variant with the aid of generating coordinates of fibers according to a law of accidental errors with different migration degrees of the 1st component followed by determination of discrimination and statistical accuracy. Discrimination is understood as the relation of absolute difference of values of the index for 2 different migration degrees to mean-square deviation of this difference.

Below is description of the suggested algorithm for calculation of index with the maximum discrimination for a sample of yarn section.

At first, position of center of gravity of the section is calculated. For this purpose:

– section is reduced to the circle (reduction algorithm is not given for reasons of space);

– distance to the center of each of N fibers is determined;

– the obtained distances are arranged in order of magnitude. Let us assume that the fiber, being the nearest to the center, takes the 1st place;

– arithmetic mean K_1 is determined from places, which are taken by fibers of the 1st component. With absolute random distribution of fibers across the section of yarn, place number, taken by any fiber, is random variable taking values 1, 2, ... N with equal probabilities $1/N$, where N – total number of all fibers in this section.

Mathematical expectation of this valueis:

$$T = \frac{(N+1)}{2}. \qquad (1)$$

For this reason the value

$$S_1 = \frac{(K_1 - T)}{T} \qquad (2)$$

may serve as a migration measure in a two-component mixture. In order for this measure to take values ±1 with full migration of the component outwards or inwards, the value S_1 is to be normalized to its value in case when fibers of the first component take first places (complete internal migration):

$$S_{1,min} = \frac{(n_1 - N)}{(N+1)}, \qquad (3)$$

where n_1 – number of fibers of the 1st component in the section of yarn.

Having divided the right part (2) by the right part (3), we obtain migration index M_1 of the first component

$$M_1 = \frac{(2S_1 - N - 1)}{(N - n_1)} \cdot 100\%. \qquad (4)$$

Migration index possesses the following properties.

1. With complete migration of fibers of first component its value corresponds to 100%.

2. With complete migration of fibers of first component outwards its value corresponds to 100%.

Migration indices of remaining components are determined by the formula (4) with the corresponding replacement of indices. For instance, migration index for second component equals to:

$$M_2 = \frac{(2S_2 - N - 1)}{(N - n_2)} \cdot 100\%. \qquad (5)$$

Migration index for two-component yarn possesses the following property: Migration index of first component equals to zero and is opposite in sign to migration index of second component.

The above stated migration indices characterize only one section of yarn. Overall evaluation is made on the basis of arithmetic mean from indices for each section. Since process of obtaining the view of yarn section is quite labour intensive, it is important to be able to predict the required number of sections to reach the predetermined statistical accuracy. In case of absolute random distribution of fiber components across the section of yarn (i.e. with no migration) the stated accuracy can be predicted. It is important to do this since statistical error with zero value of migration index, of course, will be smaller (imagine yarn with 100% migration). It is sufficient to determine root-mean-square deviation for the two-component yarn. With absolute random distribution of fiber components across the section of yarn, place number of fiber (when moving away from the center), as has been said before, is an evenly distributed value with dispertion

$$D_0 = \frac{(N^2 - 1)}{12}. \qquad (6)$$

In accordance with the sampling theory method, dispertion of arithmetic mean of place number for final assembly equals to

$$\frac{D_0 (N - n_1)(N - 1)}{n_1}. \qquad (7)$$

Taking into consideration the fact that multiplying by a constant results in changing dispertion by the square of this constant, we get dispertion of migration index:

$$D[M_1] = \frac{(N+1)(N - n_1)}{3n_1} \cdot 10000. \qquad (8)$$

Mean square deviation (MSD) of the migration index σ is

$$\sigma \approx 100 / \sqrt{3pq}, \qquad (9)$$

where $p = n_1/N$ – portion of fibers of the 1st component in section; $q = 1 – p$ – portion of fibers of the 2nd component in section.

Using (9), it is easy to determine how many sections should be examined in order to obtain a predetermined statistical accuracy. It follows from (9) that the more composition of mixture differs from 50%/50%, the more sections of yarn are to be examined.

On the basis of the proposed algorithm a computer program has been developed which enables automation of process of entering initial data and calculation of migration index.

C O N C L U S I O N S

1. On the basis of the analysis of the available migration indices and computer modeling of results of employing possible migration indices, algorithm of determination of the unbiased migration index with a minimal statistical error (from the examined ones) has been developed.

2. Maximum possible dispertion of the suggested index has been determined, which reaches minimum value for 50%/50% composition of mixture (that is true for all "correct" indices of blending).

3. A computer-assisted program for determination of migration index has been developed.

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