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A NEW SYSTEM FOR TEXTILE WEB FEEDING AT CALENDERING LINES IN TIREMAKING INDUSTRY

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Abstract

In this paper a new system for control of textile web feeding into the calendering process is presented. It consists of three stages: textile web centering, web center spreading and web edges spreading. The control of these processes is based on information on cords distribution and orientation obtained from vision sensors. Acquired vision signal processing is based on two-dimensional discrete wavelet transform. Experimental verification of this method has shown satisfactory results when real-world disturbances and real-time applicability are considered.

Key words: *Calendering process, web feeding, vision sensor, discrete wavelet transform*

1. INTRODUCTION

Passenger vehicle and truck tires are made of steel or textile cord, which is layered by rubber compound.

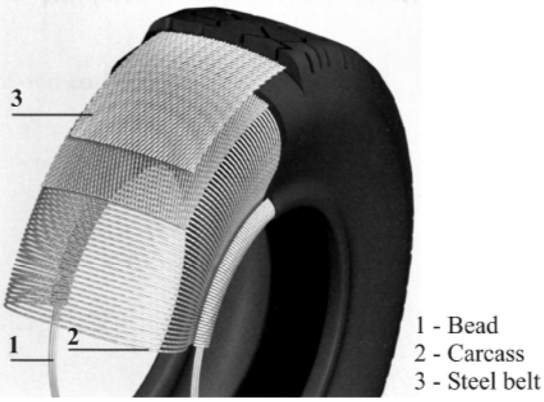

Figure 1. An example of steel cords location in truck's tire

The role of steel or textile cord is to carry the load, while the rubber compound ensures spatial position of fibers and makes the final shape of tire. An example of steel cords arrangement in truck pneumatic is shown in Figure 1. The regularity of cords distribution, their preload and mechanical bonding of textile/steel to the rubber are of the most importance for the quality of final product.

Ruberrized steel/textile cord sheets are produced using calendering technique. A pre-set number of steel cords or textile web is introduced into calender, which usually consists of 4 steel rolls in S configuration revolving in opposite direction. Rubber compound is added to the opening area between the first two rollers and it is pressed into, on the top of and on the bottom of the steel/textile cords. Continuous sheet of thus obtained composite is put trough several more rollers where, using friction and rolling, good penetration and bonding between rubber and cords is ensured.

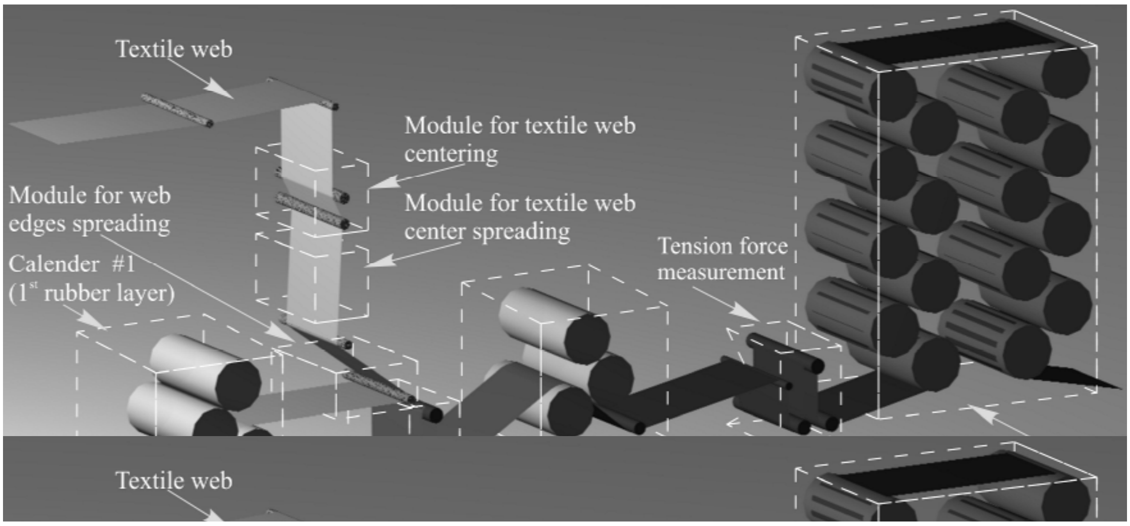

Figure 2. Flowchart of line for textile cord calendering with flowchart of textile web feeding (the line consists of 2 three-roll calenders).

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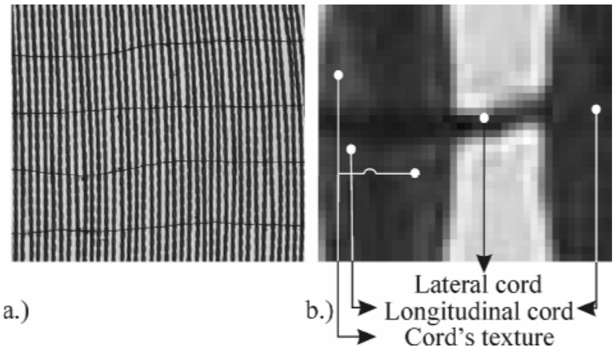


Figure 3. A shot of textile sheet

Flow chart of calendering process is shown in Figure 2, on an example of calendering line LPK-80-1800, produced in Russia, which is based on two 3-roll calenders. When steel cord is calendered, each cord is introduced into calendaring process separately. Textile cord, on the other hand, is introduced in the form of textile web (fabric) – longitudinal cords are weaved with lateral. Uniform distribution of textile cords along the whole width of the web (including its edges) is crucial for the quality of final product. A shot of textile sheet is shown in Figure 3.a. It is made of dense longitudinal cords (usually 1000 cords per 1m), weaved with relatively rare lateral cords. Deformability of lateral cords disables maintaining of pre-set geometry of textile webs. Due to unequal web spreading and due to the uneven friction torque along transport rolls, the position of longitudinal cords is lost – they become accumulated or rarefied in some areas (usually at web edges), they become inclined relative to the feeding axis, or even they can get curved shape in extreme cases. For these reasons, some corrective actions using special equipment must be carried out just before rubberizing.

In conventional systems for feeding of textile web into the process, all corrective actions of mechanisms for web centering and spreading, besides contact sensors for web edges detection, are based on a priori given parameters, following general experience rules.

In this paper, an approach to the control of uniformity of cord distribution in textile web is proposed. It is based on real time identification of cord distribution using vision sensors and two-dimensional wavelet transform of acquired signal (image).

2 SYSTEM FOR CONTROL OF TEXTILE WEB FEEDING

A flowchart of proposed system for textile web feeding control is shown in Figure 4.

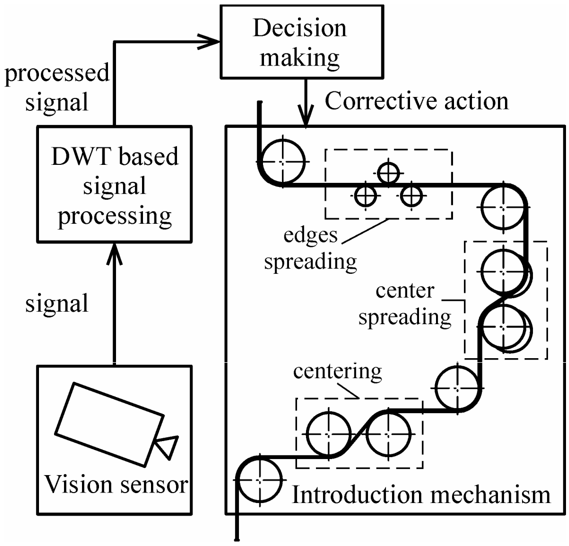


Figure 4. A flowchart of proposed control system

Acquired vision signal (image) is processed in order to obtain the information on cords distribution and orientation based on which corrective actions using feeding mechanism are carried out.

2.1. Signal processing

Identification of spacing between longitudinal cords and their orientation in respect to the longitudinal axis implies identification of each cord on static scene. This can be done by identification of left or right edge of the cord. Algorithm for identification of vertical edges interlaced with horizontal ones, in the presence of bordering noise on the edges, cord texture, as well as individual fibers stepping out, (Fig. 3.b.) is not straightforward and cannot be based on simple threshold method. Even if all edges were isolated, determining which edge belongs to the longitudinal and which one to the lateral cord (taking gradient method, e.g.) would've been extremely slow from the real time applicability point of view, and especially when the number of cords is considered.

For these reasons algorithm for cord identification is based on two-dimensional discrete wavelet transform (DWT). Using DWT signal is presented as superposition of wavelets, functions, which are obtained by translation and dilatation (in discrete steps) of single function called “mother wavelet” [1, 2, 3]. Mother wavelet and wavelets are non-periodic functions, which can be compactly supported (defined in finite time/space interval) and can be of asymmetric, irregular shapes. Thanks to these properties of wavelets, DWT is especially suitable for detection of stepwise changes in signal (such as edges in image) and their localization in time or space [3,5,6].

Multiresolution analysis (MRA) [2, 3, 4] gives fast algorithms for direct and inverse DWT computation called subbend filtering scheme. Its main results can be formulated as follows. If a sequence of resolutions 2^{-j}, $j\in(0, -\infty)$ is taken, then each signal can be represented as the sum of its approximation on resolution J – $A_J f$ and details $D_j f$, $j\in[1, J]$ taken from it during passing from higher level of approximation (resolution) to the lower one:

$$f = A_J f + \sum_{j=1}^{J} D_j f = \sum_{n} a_n^J \phi_{J,n} + \sum_{j=1}^{J}\sum_{n} d_n^j f \psi_{j,n} \quad (3)$$

where a_n^J are the approximation and d_n^j the detail coefficients, computed by above-mentioned subbend filtering scheme, $\{\psi_{j,n},\ n\in Z\}$ are the families of orthonormal wavelet bases and $\{\phi_{j,n},\ n \in Z\}$ is the family of corresponding scaling functions orthonormal basis [4].

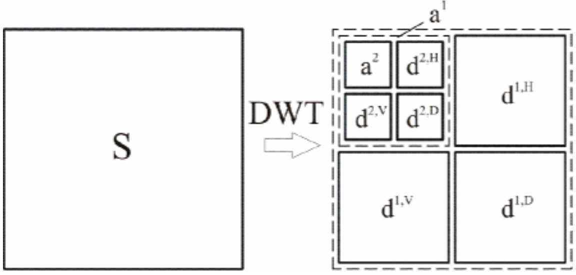


Figure 5. Two-dimensional DWT visualization

If an image is considered as two-dimensional signal (represented by matrix S with dimensions m x n, where m is the number of rows, and n the number of columns), then the edge on image can be considered as an abrupt change in space and it can be localized using two-dimensional DWT. Two-dimensional DWT is also carried out using subbend filtering scheme in following two steps:

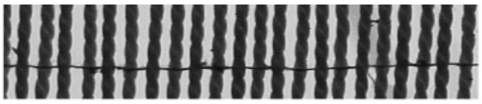
Step 1: One-dimensional DWT of each row of matrix S

Step 2: One-dimensional DWT of columns computed in step 1.

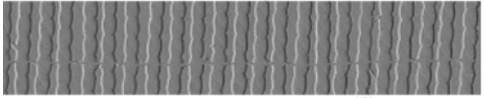
Two-level DWT of image S can be visualized as shown in Figure 5. Approximation coefficients a^1 and a^2 represent versions of starting image at 2 and 4 times lower resolutions. Detail coefficients $d^{i,H}$, $d^{i,V}$ and $d^{i,D}$ carry information on horizontal, vertical and diagonal edges in image, respectively. These matrices have 2^n (n is the level of transformation) smaller dimensions then original matrix, thus making further analysis faster, which is extremely significant from real-time applicability point of view.

2.2. Identification of distance between cords

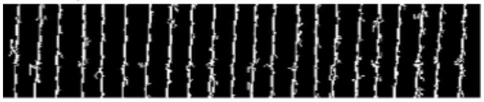
As mentioned above, identification of spacing between longitudinal cords and their orientation in respect to the longitudinal axis is based on identification of edge of each cord. In method used here it is done in three main steps [5].



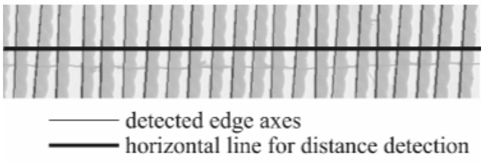
a.) Start image 1:2



b.) Vertical detail coefficients $d^{1,V}$ 1:1



c.)Vertical edges - $d^{1,V}$ after processing 1:1



d.) Detected edge axes

Figure 6. Steps in proposed edges detection method

First, one level DWT of original image (Figure 6.a.) using ‘haar’ wavelet [1, 2, 5] is carried out in order to obtain vertical detail coefficients (Figure 6.b.). Maximal values of $d^{1,V}$ (the lightest pixels in Figure 6.b.) correspond to the left, and minimal (the darkest pixels in Figure 6.b.) to the right cord edges.

Afterwards, applying threshold method on $d^{i,V}$ and putting thus obtained matrix through some additional processing [5] and low-pass filter will lead to image shown in Figure 6.c., which represents detected left edges of cords.

In third step, centroid and the angle between horizontal line and main axis of ellipse of inertia of each object on scene, that is, of each edge is computed. In this way, position and orientation of each edge on scene is determined.

Based on detected position and orientation of cord edges, their axes are determined (Figure 6.d.). The distance between cords is calculated using the distance between intersections of axis of each edge and horizontal reference line as shown in Figure 6.d. By translation of vision sensor along the web width, several images are obtained. Combining information gained from these images, the profile of longitudinal cord distribution along lateral section of textile web, that is, the profile of cords density is obtained.

2.3. Mechanism for textile web feeding

Sensory information obtained as described above, makes basis for implementation of system for control of textile web feeding into the calendaring process. Corrective actions are carried out using mechanisms dedicated for textile web centering, for textile web center spreading and for textile web edges spreading.

Due to the long infeed paths, textile web is usually inclined in infeed plane. The information on angle of inclination - α (Figure 7.) is obtained from information on cord orientation. Based on this information corrective actions are carried out using mechanism for textile web centering (Figure 7.). Main parts of this mechanism are

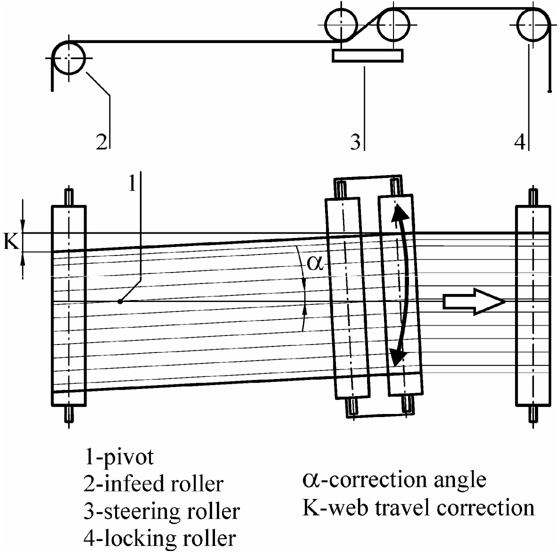


Figure 7. Mechanism for textile web centering

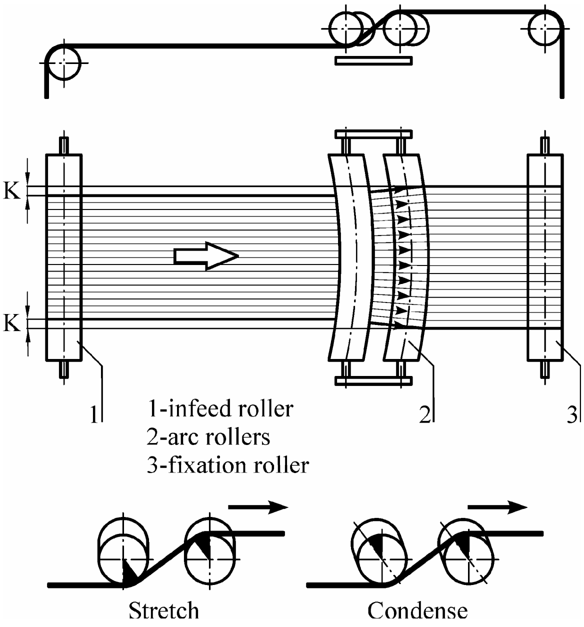


Figure 8. Mechanism for textile web center spreading

guide rollers, which rotate in infeed plane. Depending on the change of angle between guide rollers and infeed direction, the tension distribution along lateral section of web is changed, thus forcing the cords to change their direction. In this way, textile web takes demanded orientation.

Although the web is now well centered, its width and the distribution of cords within it are yet to be corrected. The mechanism for web center spreading (Figure 8.) has, as main elements, two arc (banana) rollers, separated in the center, each of them operating independently. Pivot angle between arc rollers is computed from information on cords distribution. Depending on this angle textile web is either stretched or condensed thus fixing cords distribution.

Since, due to the nature of textile web, the main errors in cord distribution appear at the web edges where the cords are usually extremely condensed, for web edges spreading special mechanism is introduced (Figure 9.). It consists of two independent three-finger rollers, which spread the cords according to its distribution obtained from vision sensor signals. Two of three rollers are fixed and are always in contact with the web, while the third is movable. The width of the web is controlled by changing the bite angle of the movable (middle) roller (β). Spreading is controlled by changing the cant angle α, while the range of influence towards the center of the web can be adjusted by changing the center gap between movable roller and web plane (G).

3. CONCLUSION

This paper gives a new approach to the control of textile web feeding into the calendering process based on textile web condition monitoring using vision sensor signal. Proposed DWT based method for monitoring of condition of textile web before its entering into the calendaring process has given good results on considered textile web samples. Two-dimensional DWT represents efficient means for detection of edges of longitudinal cords in presence of noise, lateral cords, cords texture and other real-world disturbances in image. Besides, it makes good basis for fast real-time computing of longitudinal cords distribution profile and their orientation in infeed plane. This information can be efficiently utilized for corrective actions using various mechanical mechanisms for textile web centering and spreading, as described.

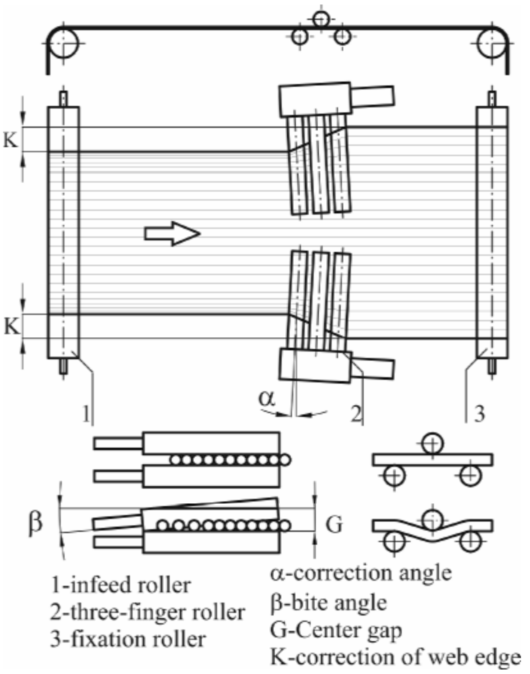


Figure 9. Mechanism for textile web edges spreading

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