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(71) Applicant *(for all designated States except US)*: **PREMIER EVOLVICS PVT. LTD.** [IN/IN]; 304, Trichy Road, Coimbatore 641 005 (IN).

(72) Inventors; and
(75) Inventors/Applicants *(for US only)*: **RAMACHANDRAN, Shekaripuram, Narayanaswamy** [IN/IN]; "Shree Nivas", N°: 3, Fourth Cross Road, Chinthamani Nagar, K.K. Pudur, Coimbatore 641 038, Tamil Nadu (IN). **KAVITHA, Narayanaswamy** [IN/IN]; Sri Sakthi Nilayam, 65/147F Teachers Colony, Podanur, Coimbatore 641 023 (IN).

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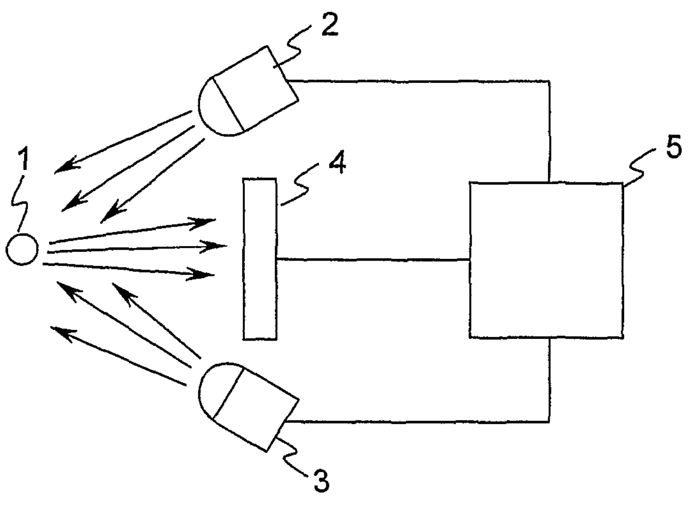

(57) Abstract: An apparatus for detecting and/or categorising foreign substances in a strand-like textile material comprises a polychromatic light source (2, 3) for emitting visible light, detectors (4) sensitive to light in the red, blue and green spectrum and arranged to measure light reflected from the textile material (1) and configured to generate corresponding red, green and blue intensity signals. A signal processing arrangement (5) is configured to determine, from the red, green and blue intensity signals corresponding values of the x and y parameters of a CIE chromaticity diagram, and to determine the presence and/or the category of a contaminant from the x and y values.

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DETECTING AND CATEGORISING FOREIGN SUBSTANCES IN A STRAND-LIKE TEXTILE MATERIAL

FIELD OF THE INVENTION

The invention relates to an apparatus and a method for detecting and/or categorising foreign substances in a strand-like textile material, i.e. for detecting the presence of contaminants in a yarn, as described in the preamble of the corresponding independent claims.

BACKGROUND OF THE INVENTION

US 6,175,408 describes a measurement apparatus emitting white light and measuring the intensity of light reflected from a travelling yarn in the red, green and blue frequency bands. For each of the three possible pairs of intensity signals a difference signal is formed. A contamination is deemed to be detected when at least one of the difference signals exceeds a given threshold. The focus of the invention is on the use of a frequency transformer for generating white light over a wider frequency spectrum, avoiding the use of narrow-band, single colour LED's.

WO 03/008950 shows a device emitting light at two different wavelengths, and having a single light receiver. Since the dependency of reflection on wavelength differs according to material, the amount of total reflected light depends on the presence and the kind of contaminant material. In this manner, it should be possible to distinguish between different contaminants.

US 5,915,279 shows a measurement setup for detecting parameters of an object in general terms. Methods for the statistical analysis of a plurality of parameters are described, e.g. light intensities detected at different wavelengths, and including time histories of intensities in order to determine deviations. However, the resulting algorithms are complicated and too general to be immediately applicable.

EP 0 652 432 A1 discloses the use of sensors for two wavelengths, with the optical arrangement ensuring that the light received by the sensors comes from exactly the same location of the yarn. From the detector signals corresponding to received intensities, a signal corresponding to a quotient (i.e. a difference of logarithms) is formed, in order to eliminate the influence of yarn diameter, structure etc.

DESCRIPTION OF THE INVENTION

It is an object of the invention to create an apparatus and a method for detecting and/or categorising foreign substances in a strand-like textile material of the type mentioned initially, which is simple to implement, improves the detection quality, and is insensitive to variations in the perception of the material that are not caused by contaminants.

These objects are achieved by an apparatus and a method for detecting and/or categorising foreign substances in a strand-like textile material according to the corresponding independent claims.

The apparatus for detecting and/or categorising foreign substances in a strand-like textile material comprises a polychromatic light source for emitting visible light, detectors sensitive to light in the red, blue and green spectrum and arranged to measure light reflected from the yarn and configured to generate corresponding red, green and blue intensity signals, and a signal processing arrangement configured to determine, from the red, green and blue intensity signals corresponding values of the x and y parameters of a CIE chromaticity diagram, and to determine the presence and/or the category of a contaminant from the x and y values. Contaminants are thus categorised and distinguished by colour, in a manner that is close to the perception of the human eye, and hence can be eliminated selectively. This is in contrast to the prior art, where detection and possibly categorisation is done according to the difference in the reflected intensities.

In the x-y representation of the observed yarn colour, the luminance z is eliminated. Thus, the analysis of the x-y signals is essentially independent of luminance. This allows the yarn analysis to focus on the actual colour of the yarn. This reduces the influence of variations in the yarn, such as hairiness, thickness etc., that are not caused by contaminants. In contrast to this, the individual intensity signals Ri, Gi and Bi commonly used as a basis for yarn analysis depend both on illumination and on the amount of light reflected in the individual colour band, which makes them sensitive to non-contaminant variations, and thus prone to errors.

In a further preferred embodiment of the invention, the presence of a contaminant is indicated whenever the distance from a current measurement point from a reference point in the x-y-plane exceeds a predetermined threshold distance value. This corresponds to an predetermined deviation of perceived colour from the colour of the base yarn.

In yet a further preferred embodiment of the invention, the reference point in the x-y-plane is determined as a moving long-term average of x and y values, and preferably only averaging values that are not associated with a contamination.

The method for detecting and/or categorising foreign substances in a strand-like textile material comprises the steps of

- emitting visible light with a polychromatic light source,
- measuring light reflected from the yarn with detectors sensitive to light in the red, blue and green spectrum and generating corresponding red, green and blue intensity signals,
- determining from the red, green and blue intensity signals corresponding values of the x and y parameters of a CIE chromaticity diagram, and determining the presence and/or the category of a contaminant from the x and y values.

Further preferred embodiments are evident from the dependent patent claims. Features of the method claims may be combined with features of the device claims and vice versa.

BRIEF DESCRIPTION OF THE DRAWINGS

The subject matter of the invention will be explained in more detail in the following text with reference to preferred exemplary embodiments, which are illustrated in the attached drawings, which schematically show:

Figure 1	testing arrangement used in the invention;
Figure 2	an array of red, green and blue sensitive detectors;
Figure 3	a chromaticity diagram in the x-y-chromaticity plane; and
Figure 4	a set of measurement points in the x-y-chromaticity plane.

The reference symbols used in the drawings, and their meanings, are listed in summary form in the list of reference symbols. In principle, identical parts are provided with the same reference symbols in the figures.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

Figure 1 schematically shows a testing arrangement used in the invention. A yarn 1 is illuminated by one or more polychromatic light sources such as white light emitting diodes (LED) 2,3. Light reflected from the yarn is detected by a detector array 4 comprising three groups of detectors, each group being sensitive to a specific range of wavelengths. The total signal of each group represents the intensity of the light received in said range. The individual detector signals or the total signal of each group are processed by a signal processing circuit 5.

Figure 2 shows an exemplary array of red, green and blue sensitive detectors, denoted by the letters R, G, B. The detector array is arranged to receive light from a particular section of the travelling yarn 1 and is able to sample measurements from each individual detector simultaneously. The individual detectors are inter-digitated in order to ensure a uniform irradiance of each group of detectors.

The signal processing circuit 5 determines, by analog or digital signal processing circuits, x and y parameters of the CIE chromaticity diagram corresponding to the detected light intensities. The CIE system characterises colours by a luminance parameter and two chromaticity coordinates x and y which specify a point on the chromaticity diagram (Figure 3). The chromaticity coordinates map the colour with respect to hue and saturation on the two-dimensional CIE chromaticity diagram. Any colour on the CIE chromaticity diagram can be considered to be a mixture of the three CIE primaries, X,Y,Z. That mixture may be specified by three numbers X,Y,Z called tristimulus values. The CIE primaries or tristimulus values X,Y,Z uniquely represent a perceivable hue.

The ideal, theoretical procedure for obtaining the chromaticity coordinates for a given coloured object involves the following steps:

1. Measuring the spectral power distribution at each wavelength.
2. Multiplying by each of three colour matching functions.
3. Summing to get the three tristimulus values X,Y,Z.
4. Normalising the tristimulus values by dividing with (X+Y+Z), giving x, y, z.

The x and y are the chromaticity coordinates. Since the luminance z=1-x-y, it offers no additional information.

The practical procedure, according to a preferred embodiment of the invention avoids the measurement of the complete spectral power distribution. Instead, intensity measurements at three wavelengths, typically in the red, green and blue areas, are made, and transformed to give the three tristimulus values X,Y,Z. Thus, the signal processing arrangement is configured to determine the X, Y, Z CIE coordinates according to

$$\begin{vmatrix} X \\ Y \\ Z \end{vmatrix} = \begin{vmatrix} a_{11} & a_{12} & a_{13} \\ b_{21} & b_{22} & b_{23} \\ c_{31} & c_{32} & c_{33} \end{vmatrix} \cdot \begin{vmatrix} Ri \\ Gi \\ Bi \end{vmatrix}$$

where Ri, Gi, Bi are values of the red, green and blue intensity signals, respectively. The signal processing arrangement is further configured to normalise the tristimulus values by determining the x and y values as

$$x = \frac{X}{X+Y+Z} \qquad y = \frac{Y}{X+Y+Z} \quad .$$

The matrix coefficients a11 ... c33 are determined e.g. by calibrating the apparatus with known reference colours. Their values then incorporate a compensation of spectral power distribution of the illumination source, of the spectral reflectance of the sample or the test material, of the attenuation of optical filters and of the sensitivity of the detectors. The values of the coefficients also depend on the version of the CIE chromaticity diagram that is used (1931, 1960, 1976).

Figure 4 shows a sample plot of a series of measurement points in the x-y plane. The measurement points were obtained at different locations along a test yarn 1. A cluster of points is determined from a reference yarn or from a long term average observed during production. An average of the cluster positions defines a reference point. For each set of red, green and blue intensity measurements, the corresponding x-y values are determined and the distance d from the reference point is computed. If the distance from the reference point exceeds a certain predetermined threshold, this is interpreted as the presence of a contaminant, and appropriate action is taken, e.g. cutting out the contaminant. When categorising contaminants, the system is, in a preferred embodiment of the invention, controlled only to cut out contaminants belonging to specific, predetermined categories of contaminants.

When categorising contaminants, the location of a measurement point in the x-y plane is evaluated with respect to a plurality of reference points or reference areas. Each reference point or reference area represents either the base material or one of a group of contaminant classes. Commonly known classification and clustering algorithms for two-dimensional vectors are applied.

Depending on the application, the reference points or associated areas or clusters thus represent e.g. cotton, contaminants such as cotton seeds, Human/Animal Hairs, polyethylene (PE), polypropylene (PP), etc.

LIST OF DESIGNATIONS

1	yarn
2, 3	light emitting diodes
4	detector array
5	signal processing circuit

PATENT CLAIMS

1. An apparatus for detecting and/or categorising foreign substances in a strand-like textile material comprising a polychromatic light source (2, 3) for emitting visible light, detectors (4) sensitive to light in the red, blue and green spectrum and arranged to measure light reflected from the textile material (1). and configured to generate corresponding red, green and blue intensity signals, and a signal processing arrangement (5) configured to determine, from the red, green and blue intensity signals corresponding values of the x and y parameters of a CIE chromaticity diagram, and to determine the presence and/or the category of a contaminant from the x and y values.

2. The apparatus of claim 1, wherein the signal processing arrangement (5) is configured to determine X, Y, Z CIE coordinates according to

$$\begin{vmatrix} X \\ Y \\ Z \end{vmatrix} = \begin{vmatrix} a_{11} & a_{12} & a_{13} \\ b_{21} & b_{22} & b_{23} \\ c_{31} & c_{32} & c_{33} \end{vmatrix} \cdot \begin{vmatrix} Ri \\ Gi \\ Bi \end{vmatrix}$$

where Ri, Gi, Bi are values of the red, green and blue intensity signals, respectively, and the signal processing arrangement (5) is further configured to determine the x and y values as

$$x = \frac{X}{X+Y+Z} \qquad y = \frac{Y}{X+Y+Z} \quad .$$

3. The apparatus of claim 1 or 2, wherein the presence of a contaminant is indicated whenever the distance from a current measurement point from a reference point in the x-y-plane exceeds a predetermined threshold value.

4. The apparatus of claim 3, wherein the reference point in the x-y-plane is determined as a moving long-term average of x and y values not associated with a contamination.

5. A method for detecting and/or categorising foreign substances in a strand-like textile material comprising the steps of
   - emitting visible light with a polychromatic light source (2, 3),
   - measuring light reflected from the textile material (1) with detectors sensitive to light in the red, blue and green spectrum and generating corresponding red, green and blue intensity signals,
   - determining from the red, green and blue intensity signals corresponding values of the x and y parameters of a CIE chromaticity diagram, and determining the presence and/or the category of a contaminant from the x and y values.

6. The method of claim 5, comprising the steps of
   - determining X, Y, Z CIE coordinates according to

$$\begin{vmatrix} X \\ Y \\ Z \end{vmatrix} = \begin{vmatrix} a_{11} & a_{12} & a_{13} \\ b_{21} & b_{22} & b_{23} \\ c_{31} & c_{32} & c_{33} \end{vmatrix} \cdot \begin{vmatrix} Ri \\ Gi \\ Bi \end{vmatrix}$$

     where Ri, Gi, Bi are values of the red, green and blue intensity signals, respectively, and then
   - determining the values of the x and y parameters of the CIE chromaticity diagram as

$$x = \frac{X}{X+Y+Z} \qquad y = \frac{Y}{X+Y+Z} \quad .$$

7. The method of claim 5 or claim 6, wherein the contaminant is determined to be in one of a set of categories of contaminants, said set of categories comprising at least one or two or more of
   - a category corresponding to materials similar to polypropylene, polyethylene;
   - a category corresponding to materials similar to human/animal hairs, feathers;
   - a category corresponding to materials similar to jute, trash, cotton seeds;
   - a category corresponding to materials similar to coloured yarns.

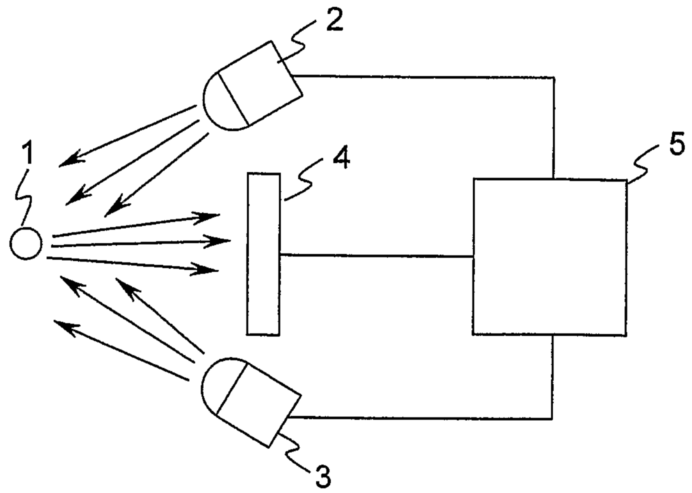


Fig. 1

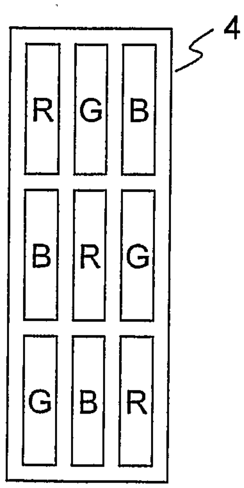
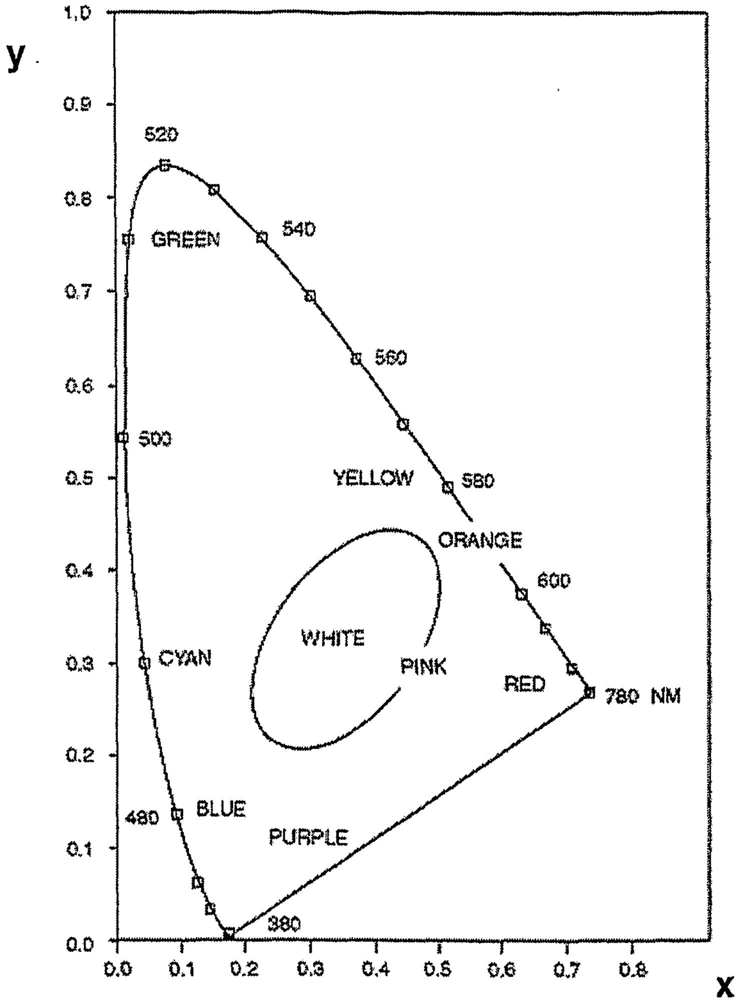


Fig. 2



y
x
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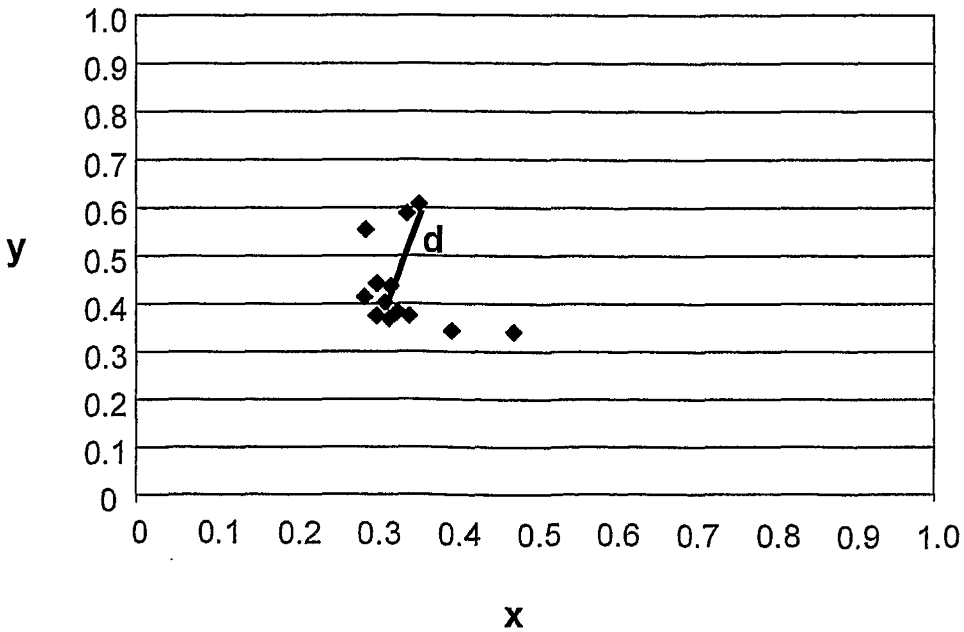
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0.0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8
520
540
560
580
600
500
480
380
780 NM
GREEN
YELLOW
ORANGE
WHITE
PINK
RED
CYAN
BLUE
PURPLE

Fig. 3



y
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0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0

Fig. 4