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(54) **Photoelectrical measuring method and apparatus**

(57) The position of a reflecting surface B (or A) determines the direction in which a light beam 2 from a source 1 finally impinges, via a lens 4, onto a bank of light detectors 5, and by ascertaining 6 which detector 5 has the largest output the position of the surface can be determined.

Fig.1.

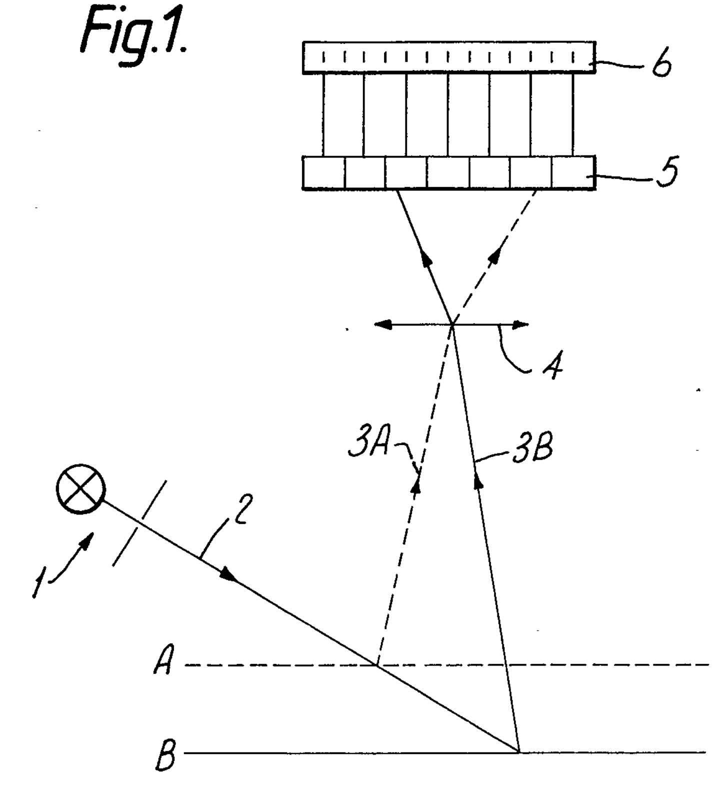

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Fig.1.

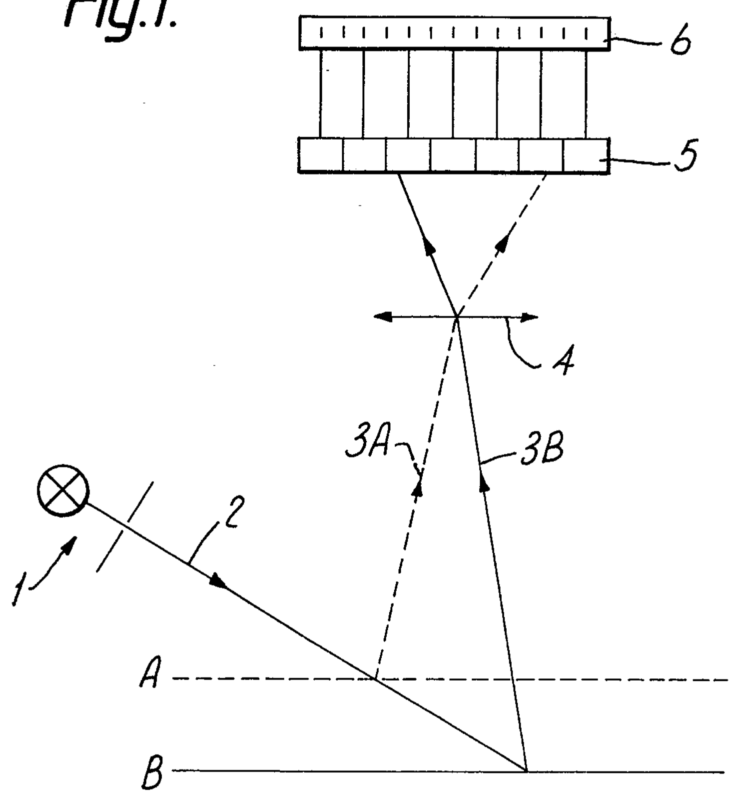
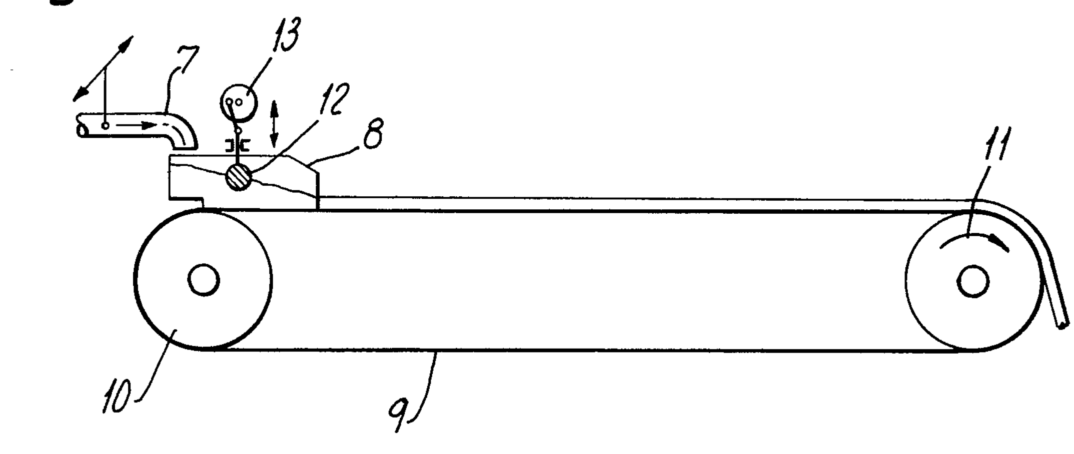


Fig.2.



SPECIFICATION

Photoelectrical measuring method and apparatus

It is known to control the height of a liquid or powder by shining a light beam onto the surface of liquid or powder so that it is reflected into a photoconductive cell, suitably via a reflecting mirror, and monitoring the output voltage (which varies according to the angle of incidence of the light reflected from the surface) of the cell. However, this method does not readily allow the observation or control of the level of liquids or powders having a surface which is not smooth.

According to the present invention, measurement apparatus comprises a plurality of sensors each capable of delivering an illumination-dependent output and each associated with a particular angle of incidence of illumination, and means for displaying the output of the sensors.

According to a further aspect of the invention, a method for measuring the distance of a sample, in a monitoring zone thereof, from a light-sensitive receiver, comprises shining a beam of light onto the zone, and imaging the zone on the receiver, the receiver comprising a plurality of sensors each capable of delivering an illumination-dependent output and each associated with a particular angle of incidence of illumination, and observing the relative outputs of the sensors.

The present invention is based on the fact that a light beam projected on a surface at an acute angle thereto forms a light spot thereon which shifts along the surface to a degree proportional to the vertical distance of the surface from the light source. The smaller of angle of incidence of the beam, the greater the shift for a given change in the height of the surface. Accordingly, when a light beam is shone at an angle onto a sample to form a spot in a monitoring zone in the sample, the position of the spot will change depending on the height of the sample and the light-sensitive receiver which is used in the invention will deliver a varying output according to the position of the spot since the angle of incidence of light from the spot with reference to the receiver will change.

In order to allow maximum sensitivity, it is desirable that the shift of the light spot on the sample for a given change in height should be as great as possible and that, therefore, the angle of incidence of the beam with respect to the sample should be as small as possible. However, the lower the angle, the greater the size of the light spot and the greater the area lit up by stray or scattered light. This is undesirable since the image may be poorly defined, particularly when the sample has a rough surface. It is therefore usually advantageous to determine the most suitable angle of incidence in any given case by a simple preliminary test. Nevertheless, if a small diameter beam of convergent light is used, a small angle of incidence can be chosen and correspondingly great sensitivity and accuracy of measurement can be achieved.

The receiver can be aligned at any angle to the sample except that, of course, it may not lie in the direction of the light source or beam incident on the sample. Generally, the light beam incident on the sample and the receiver will lie in a plane generally perpendicular to the surface of the sample.

The distances at which the light source and the receiver are arranged from the monitoring zone are not critical. Accordingly, they can be located outside regions close to the sample in which it is possible that the results might be falsified by local influences. The invention is thus very suitable for use in the measurement of the thickness of any materials from a distance away, e.g. materials which cannot be contacted directly.

The distance of a sample from the receiver, and consequently its thickness if the distance from the surface on which the sample is resting to the receiver is also known, can be observed qualitatively by checking which sensor is delivering an output. In most cases, however, no one sensor alone will deliver a signal, and sensors associated with only slightly different angles of incidence will deliver lesser outputs. Such an effect is caused by the scattering of light at the surface of the sample and can be reduced by processing only those output voltages from given sensors, either which exceed a certain minimum value, or which are the maximum value for that sensor. In any given case, with this provision, a minimum of sensors should deliver an output and, with suitable calibration, actual distance of the sample from the receiver can be read off directly from a suitable scale.

The invention can be used for the observation of materials whose thickness varies, e.g. sinusoidally, in their direction of production. For example, it is often desirable to observe the thickness of incompletely hardened artificial leather having a variable surface as it runs over a conveyor belt in production, or when a liquid or powder is being levelled by shaking or paddling. In such circumstances, when using the method and apparatus of the invention, the sensors associated with the range of thicknesses of the sample will be variably illuminated between a minimum and a maximum value. By simple integration of the two values in conventional manner, an average value can be obtained, which can be directly calibrated to an absolute value. In the manufacture of materials passing continuously through the monitoring zone, the relevant scale can be calibrated, if desired, to observe any or each relevant value. The integration of the maximum and minimum values can be carried out by determining the period of variation and observing the individual sensor which carries the maximum output signal half-way through the period.

It is usually preferred to provide the plurality of sensors in a plane arrangement, and with an illumination-proportional voltage output, each sensor being connected to measuring and/or control apparatus which, if necessary, contains an integrator for the voltages. A suitable arrangement may comprise, for example, a point source of light and a receiver in the form of a television camera connected to an image-screen or display apparatus, the matt glass of which is provided with a scale showing the various distances of the camera from the surface of the sample. The camera may be arranged perpendicularly above the monitoring zone and the point source may be arranged in a plane parallel to the bottom edge of the receiver. The angle of incidence of the beam from the source on the sample will usually be from 10 to 70°.

In order to obtain a satisfactory evaluation in the case of materials having a rough surface or a periodically varying surface parallel to, or moving perpendicularly to, the receiver, it is necessary to produce a mean value from a plurality of measurements. This evaluation may be effected quantitatively by determining which sensor provides the maximum intensity and by subsequent determination of the mean value for a plurality of successive measuring cycles.

Qualitative evaluation of the voltages delivered by individual sensors may be used, for example, to bring the reflection behaviour or the surface roughness of the sample in the monitoring zone continuously into relationship with the relevant average values of the entire surface. In this way, certain quality standards of the surface can be observed and checked fully automatically.

In view of the fact that the position of the light spot on the sample remains on a straight line as the thickness of the sample changes, it is simplest if the sensors are assembled or combined in the receiver in a straight line disposed parallel to the plane of the beam of light. Various elements may be employed as individual sensors; examples are photoconductive cells, photodiodes and photodiode arrays. The necessary electrical circuits can be constructed in a manner which will be readily apparent to one skilled in the art.

The excitation of the sensors will usually be caused by the diffuse reflection from the light spot in the monitoring zone. While directly reflected light may be used in this invention, this is less desirable when the sample is not smooth or is a poor reflector.

It is usually preferred that there should be at least n sensors in the receiver, where n is 4, 6, 8 or 10. The imaged light spot can be projected true to scale on the display means associated with the receiver.

The invention will now be described by way of example with reference to the accompanying drawings, in which:

Figure 1 is a schematic representation of apparatus of the invention in use; and

Figure 2 is a schematic representation of apparatus for the production of a sample of the type whose surface properties can be observed using the method and apparatus of the present invention.

Figure 1 shows a light source 1 giving a light beam 2 directed onto a monitoring zone on a sample. The surface of the sample may be at level A or level B. Depending on whether the light beam 2 is incident on the sample at level A or B, respectively, the light passing to the receiver from the monitoring zone is indicated by path 3A or 3B.

The receiver, comprising a lens or lens system 4 and a plurality of individual sensors 5, is arranged directly above the monitoring zone. The response of each sensor can be reproduced on a suitably calibrated scale 6 using, if desired, suitable integration means (not shown).

If the angle of the light beam 2 with respect to the vertical is α, the vertical distance between levels A and B is h, and the horizontal distance between the points at which the light beam illuminate the sample at the two levels is l, then:

$$l = h \tan \alpha.$$

Where the surface of the sample varies, periodically, it will be desirable initially to check that each sensor is illuminated at some point in the period to confirm that the surface of the sample is within a certain distance from the receiver. It is then simply necessary to calibrate the scale employed in order to allow an indication of the thickness of the sample. Owing to the undulating movement of the sample in the monitoring zone various samples with different values are obtained on comparison of the results. These may vary, for example, from 1 to 2 mm, It is then necessary to calculate a mean value, taking into account the factor which causes the oscillation. Where the variation is sinusoidal, the value of the thickness of the layer in the given case would be 1.5 mm. It will be readily apparent that any marked change can easily be observed.

The described evaluation method is based on the simple assumption that only the output voltage of a sensor having the maximum illumination is processed. This method has the advantage that the indication is independent of the absolute level of the particular maximum value and, consequently, of the possibility of the varying reflection behaviour of the sample. When carried into effect correspondingly, the method of the invention can be directly employed, without intermediate adjustment, for measuring the thickness of materials of varying surface structure and colour. This is of importance for the widespread applicability of the invention. It will be appreciated that it may sometimes be necessary to amplify the signals obtained from individual sensors.

Figure 2 illustrates apparatus used in the preparation of a non-woven fabric. An aqueous fibre suspension is supplied through a pipe 7 to a chest 8 having an open front. An endless belt 9 consisting of a wire gauze passes continuously at a uniform speed over rollers 10 and 11 and under the chest 8. The fibre suspension is carried on the gauze, through which water in the suspension passes so that the product is drawn off the belt as a dry, strong, non-woven.

In order to provide uniform distribution of the suspension over the width of the belt 9, the pipe 7 reciprocates transversely and a paddle consisting of a cylindrical body 12 extending over the entire width of the belt, and driven by an eccentric drive 13, oscillates in the suspension. The waves produced in the suspension by this movement effect its uniform distribution.

The ratio of the thickness of the layer of the suspension before removal of the water to the same layer after removal of the water may be from 100:1 to 10000:1. With automatic control of the amount of suspension supplied per unit time, it is therefore desirable to locate the monitoring zone, when the surface of the non-woven is observed by the method of this invention, as near as possible to the chest, in order to obtain desirably high accuracy of measurement. The surface of the suspension is not uniform in this zone, but has an undulating profile.

CLAIMS

1. Apparatus comprising a plurality of sensors each capable of delivering an illumination-dependent output and each associated with a particular angle of incidence of illumination, and means for displaying the output of the sensors.

2. Apparatus according to claim 1 in which only those sensor outputs above a given minimum output are displayed.

3. Apparatus according to claim 2 in which only the maximum output of each sensor is displayed.

4. Apparatus according to claim 1 substantially as illustrated in Figure 1 with reference to the description herein.

5. A method for measuring the distance of a sample in a monitoring zone from a light-sensitive receiver, which comprises shining a beam of light onto the zone, and imaging the zone on the receiver, the receiver comprising a plurality of sensors each capable of delivering an illumination-dependent output and each associated with a particular angle of incidence of illumination, and observing the relative outputs of the sensors.

6. A method according to Claim 5 in which the receiver is in the form of apparatus according to any of claims 1 to 4.

7. A method according to claim 5 or claim 6 in which the beam of light is convergent.

8. A method according to any of claims 5 to 7 in which the sensors are arranged side-by-side in a straight line which is parallel to the plane of the beam of light.

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