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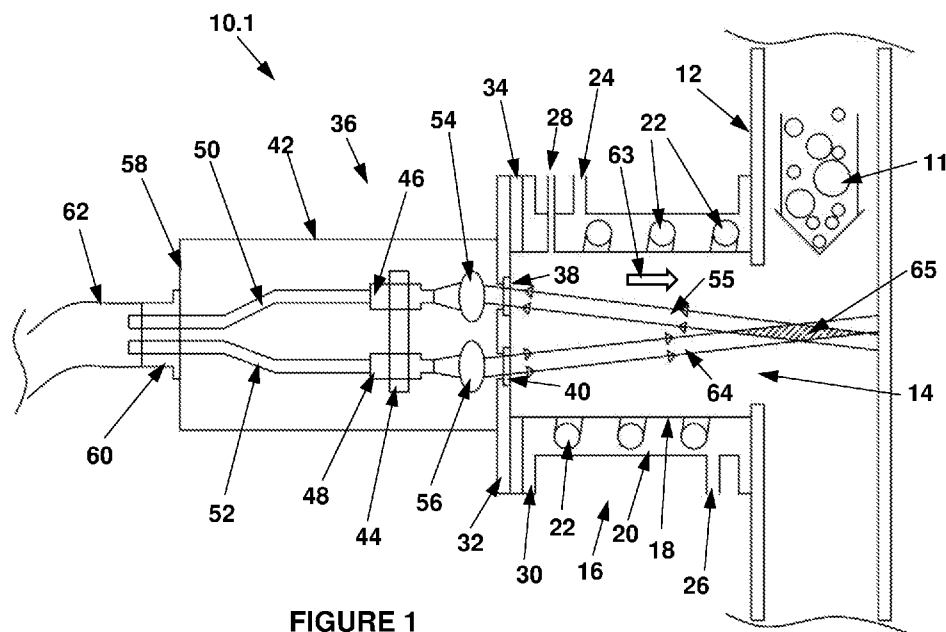


FIGURE 1

(57) Abstract: A sensor structure (10) is used for obtaining data from a moving stream of particulate material (11), with a light source (56) providing a focussed light beam (64) to illuminate the particles (11) and a light receiver (54) receiving light reflected off the illuminated particles (11) and transmitting the light to an optical sensor. The light from the illuminated particles (11) in a small analysis zone (65) is analysed during short intervals, so that light from only one particle is analysed at a time. The light from a large number of individual particles (11) is analysed separately and an analysis result is calculated from the analysis of the light reflected from the multiple individual particles (11).



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OBTAINING DATA FROM A MOVING PARTICULATE PRODUCT

FIELD OF THE INVENTION

5 This invention relates to a sensor structure for obtaining data from a moving particulate product. The invention is useful for hot, flowing particulate product, but it is also useful in many other applications, such as product on a conveyor belt or in several other modes of transport.

BACKGROUND TO THE INVENTION

10 The flowing calcined product stream from a calcining kiln is at a temperature which is sufficiently high to cause the rocks that constitute the product to glow. It is desirable to be able to analyse the product stream thereby to determine the characteristics of the product emerging from the kiln. This enables the operating parameters of the kiln to be adjusted to obtain product of optimum quality. Specifically, in a lime calcining process, it
15 is desired to optimise the amount of chemically available lime and the proportion of chemically available lime to that of slow reacting lime. In the industry this is known as detecting the “burntness” level of the product.

The calcined lime comprises lumps that are known as rocks and also comprises dust.
20 The rocks are of a wide range of sizes. The term “particulate” is used herein to include the form of calcined material which emerges from a lime kiln – as well as various other forms of moving product comprising solid particles.

The present invention provides a sensor structure which obtains spectral data from the
25 glowing rocks in a stream of calcined lime.

The sensor structure can be used in respect of any other product which comprises a flowing stream of rocks heated to a temperature sufficient to cause them to glow, or in respect of any other product which comprises a moving stream of particles.

BRIEF DESCRIPTION OF THE INVENTION

According to a first aspect of the present invention, there is provided a sensor structure for obtaining data from a moving stream of particulate material, the sensor structure comprising:

a light transmitter which is adapted to produce light in a focussed light beam, for illuminating particles in the moving stream; and

a light receiver which is adapted to receive light reflected off the illuminated particles and to transmit the light to an optical sensor;

wherein the light transmitter and the optical sensor are configured to analyse the light reflected off the illuminated particles or emitted by the illuminated particles, during intervals shorter than a period required for a particle of typical size to pass before the focussed light beam;

wherein a focus angle of the light transmitter and an acceptance angle of the light receiver are configured to analyse the light reflected off the illuminated particles or emitted by the illuminated particles, from an illumination or analysis zone with a size that is at most as large as a size of a typical particle in the stream of particulate material.

The light source may be adapted to produce light continuously and the optical sensor may be adapted to analyse the reflected light intermittently, or the light source may be adapted to produce flashes of light at timed intervals

The light source may be a laser, e.g. a pulsed laser.

The light receiver may have an axis that intersects the focussed light beam at a non-zero, acute angle, so that it is adapted to receive the reflected light along a path which intersects the focussed light beam.

The light receiver may have an axis that coincides with the focussed light beam at a zero angle and with no displacement, so that it is adapted to receive the reflected light along at least part of the same path as the focussed light beam.

5 The focussed light beam may be focussed close to infinity, also known as a collimated beam.

The acceptance angle of the light receiver may be close to zero.

10 The light transmitter may comprise a light source, a first optical fibre and a focussing lens, the first optical fibre having an inlet end and an outlet end and the light transmitter being configured so that light from the light source passes from the inlet end of the first optical fibre to emerge at the outlet end and light emerging from the outlet end passes through the focussing lens to form the focused light beam.

15 The receiver for reflected light may comprise a second optical fibre having an entrance end, and a lens, the lens being adapted to collect light reflected off the illuminated particulate material and launch it into the entrance end of the second optical fibre.

20 The sensor structure may include a casing which has an end wall including at least one window, the sensor structure being configured such that the focussed light beam transmitted from the light transmitter and the light reflected off the illuminated particulate material, pass through the window at spaced locations.

25 The sensor structure may include two spaced apart windows, configured such that the focussed light beam transmitted from the light transmitter and the light reflected off the illuminated particulate material, pass through different windows.

The sensor structure may include a manifold defining a passage for a cooling medium, the manifold forming an extension of the casing and being adapted to be fastened to a flow channel down which the particulate material falls. The end wall of the casing may also constitute an end wall of the manifold.

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The sensor structure may include an air inlet adapted to inject air into the manifold, and the sensor structure may be configured for the air injected through the air inlet to flow inside the manifold away from the window and towards the flow channel.

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According to another aspect of the present invention there is provided a method of obtaining data for analytical purposes from a flowing stream of particulate product, the method comprising:

illuminating particles in the flowing stream by directing a focussed beam of light at the flowing stream;

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collecting light reflected from the particles in the flowing stream;

feeding the reflected light that is collected to an optical sensor; and

separately analysing the light reflected off a plurality of individual particles of the illuminated particles, by separately analysing the light reflected of each of the individual particles during an interval that is shorter than the period required for a

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particle of typical size to pass before the focussed light beam; and

calculating an analysis result from the analysis of the light reflected from the plurality of the individual particles.

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The method may include illuminating the particles at timed intervals by pulsing the focussed beam of light to illuminate the particles in the flowing stream for periods that are shorter than the period required for a particle of typical size to pass before the focussed light beam.

The method may include illuminating the particles continuously with the focussed light beam and analysing the light reflected of the particles intermittently for periods that are shorter than the period required for a particle of typical size to pass before the focussed light beam.

The method may include shaping an angle of the focussed light beam to illuminate an area the size of a particle of typical size, or less. Instead, or in addition, the method may include shaping an acceptance angle of the light receiver to cover an area the size of a particle of typical size, or less.

The angle from which reflected light is collected may intersects the focused light beam at a non-zero, acute angle.

The flowing stream may comprise a hot, incandescent particulate product.

BRIEF DESCRIPTION OF THE DRAWINGS

For a better understanding of the present invention and to show how the same be carried into effect reference will now be made, by way of example, to the accompanying drawings in which:

Figure 1 is a diagrammatic representation of a first embodiment of a sensor structure according to the present invention; and

Figure 2 is diagrammatic representation of a second embodiment of a sensor structure according to the present invention.

DETAILED DESCRIPTION OF THE DRAWINGS

Referring to both drawings, reference sign 10 refers generally to a sensor structure for obtaining data from a calcined product stream for analysis purposes and the same reference signs are used in both drawings to identify features that are substantially similar between the two embodiments, but appendices are used to distinguish between

the sensor structures generally, as 10.1 and 10.2, respectively.

Referring to Figure 1, the sensor structure 10.1 illustrated is fitted to a flow channel in the form of a chute 12 down which calcined lime from a lime calcining kiln falls. The calcined lime is in freefall, is glowing hot and in the form of what are referred to as “rocks” 11. There is also dust in the chute 12.

The chute 12 has an opening 14 in the side wall thereof and a manifold 16 is secured to the chute in alignment with the opening 14. The manifold 16 comprises an inner cylindrical wall 18 which is surrounded by a coaxial water jacket 20. Within the jacket 20 there is a coil 22 which guides flow of cooling water which enters through an inlet 24 and exits through an outlet 26.

An air inlet to the manifold is shown at 28 and an end flange of the manifold 16 is shown at 30. An end closure plate 32 for the manifold 16 is secured to the flange 30. A gasket 34 is provided between the flange 30 and the end plate 32 to limit heat transfer from the manifold 16 to the plate 32. The plate 32 also forms part of an optical scan head generally designated 36.

The plate 32 can have a single window in it but preferably has two windows 38 and 40.

The scan head 36 comprises an outer casing designated 42 within which there is a transverse mounting 44. The mounting 44 carries two optical fibre termination units 46 and 48 for two optical fibres, a first optical fibre 52 and a second optical fibre 50. Between the optical fibre termination unit 48 and the window 40 of the plate 32 there is a lens 56 which produces a beam 64 of light. The beam 64 passes through the window 40 and the manifold 16 so that, in use, it illuminates calcined material 11 falling down the chute 12.

Between the optical fibre termination unit 46 and the window 38 there is a lens 54 which, in use, collects light reflected from the calcined material 11 and launches it into the second optical fibre 50 at the termination unit 46.

5 A rear plate 58 of the head 36 has an opening in it and a hose gland 60 is fitted into this opening. A protective hose 62 is attached to the gland 60 and the optical fibres 52, 50 run through this to, respectively, a light source and an optical sensor such as a spectrometer.

10 In use the incandescent rocks 11 of the calcined lime, with a quantity of dust, fall down the chute 12. Water is pumped through the jacket 20 and circulates around the coil 22 so that heat is conveyed away and overheating of the head 36 is prevented. Dust free air is blown in through the inlet 28 and flows into the chute 12 through the manifold 16. Having a higher pressure adjacent the windows 38 and 40 causes a flow of air in the manifold in a purge direction 63 away from the windows and towards the opening 14
15 and thus prevents or inhibits dust settling on the windows and attenuating both the transmitted light beam 64 and light 55 reflected off the flowing product stream 11.

Light in the form of flashes is launched into the optical fibre 52 from the light source.
20 The light shining out of the optical fibre 52 is shaped by the lens 56 into a beam 64 which illuminates the flowing stream.

As illustrated, the optical fibre termination unit 48 is at an acute angle with respect to the optical fibre termination unit 46 which receives light reflected off the rocks 11. The light
25 beam 64 is transmitted as a pencil beam and illuminates the rocks as they fall through the beam. The light reflected from the rocks scatters in all directions and the reflected light which passes through the window 38 to the lens 54 is collected by the lens and focused on the optical fibre 50 at termination unit 46.

As shown by the hatched area which represents an illumination or analysis zone 65, light reflected from practically the entire width of the stream of rocks 11 falling in the chute 12 can reach the termination unit 46 if appropriately reflected. The width of the analysis zone 65 is a result of the small acute angle between the emitted light beam 64 and the reflected light 55 that is collected by the lens 54.

Because the transmitted and reflected light pass through separate windows 38 and 40, or through spaced parts of the same window (in other embodiments of the invention), the likelihood that light from the transmitted light flashes would scatter off dust on the window, reach the lens 54 and be accepted by optical fibre 50, is minimised.

The received light is converted into a discrete digital array of intensity values by means of a digital spectrometer. Each value in the array represents the intensity of a photo sensitive pixel that has accumulated the light of a particular wavelength range. These scanned spectra are processed in computer software at regular intervals.

At each interval, the scanned spectrum is correlated with a set of five pre-defined spectral signatures. (The number of signatures could be different in other embodiments of the invention.) The five correlation results are stored as one record in a FIFO (First In First Out) buffer. An analysis result is calculated by iterating through the buffer and comparing the correlation values against threshold values, then applying conditional logic to evaluate whether that spectral sample scan can be counted as a rock or not. In the case of a rock, it is further evaluated whether the rock can be counted as burnt or not.

An output value of "rocks" is the total amount of records in the buffer that were evaluated and can be counted as a rock. The output value of "burnt rocks" is calculated as a percentage where the amount of records in the buffer that can be counted as both

a rock and burnt is expressed as a percentage of the total amount of counted rocks in the buffer.

As the FIFO buffer is updated at regular intervals, it contains a set of records of the most recent correlation results, after being filled up for the first time. Sensor output values will therefore be current and when the number of counted rocks is high enough, the output values will be based on a statistically significant number of "experiments" to be representative of the stream of rocks 11.

The light source must have a lumen value sufficient to provide the spectrometer with light of sufficient brightness to enable it to process the light and obtain useful results. If a light source that provides continuous illumination is used, then it is the spectrometer that can be switched so as effectively to provide snapshots of the falling rocks.

It is desirable to take only one snapshot of each falling rock. Consequently the time between flashes (or the triggering of the spectrometer) is such as to ensure that a rock that has been illuminated falls out of the analysis zone 65 before the next snapshot is taken. The duration of the light pulse or the integration time of the spectrometer is preferably short enough to ensure that only one rock was illuminated and therefore examined during the duration of a single pulse or integration time.

Similarly, it is desirable that each snapshot includes only one falling rock and accordingly, the illuminating light beam 64 and/or the reflected light beam 55 preferably have a size (a cross-sectional area) that is the same approximate size, or preferably smaller, than the size of a typical rock – so that the analysis zone 65 has a size that is the same or less than the size of a typical rock. The size of the analysis zone 65 can be kept small by keeping a focus angle of the light transmitter and/or an acceptance angle of the light receiver small enough.

Referring to Figure 2, a second embodiment of a sensor structure 10.2 is shown that is similar to the sensor structure shown in Figure 1. In particular, the chute 12 and manifold 16 are identical between the two illustrated embodiments, and so is the overall external structure of the optical scan head, with a mounting 44, optical fibres 50,52 termination units 46,48 and lenses 54,56.

Instead of two separate windows in the end closure plate 32, the sensor structure 10.2 includes only a single window 39. Reference was made when describing Figure 1, that a single window could be used in the first embodiment of the sensor structure 10.1 with illuminating and reflected light passing through different locations in such a window, but the significant difference between the embodiments shown in Figures 1 and 2, is that illuminating and reflected light pass through a single location in the second embodiment of the sensor structure 10.2 – thus necessarily requiring only a single window 39.

A mirror 67 and beam splitter 66 are provided in the optical scan head 36 between the window 39 and the lenses 56,54. The mirror 66 is disposed in the optical path of the illuminating light beam 64 emitted from the lens 56 at an acute angle. The mirror 67 is shown at an angle of 45 degrees, but the angle could be varied in other embodiments. The beam 64 emitted from the lens 56 is reflected by mirror 67 onto beam splitter 66 where part of beam 64 passes through beam splitter 66 and is discarded (e.g. by capturing it on a matt black surface) while the remainder of beam 64 is reflected by beam splitter 66 and travels through window 39 to become the illuminating light beam 64.

Of the light reflected off a falling rock 11 in the chute 12, the reflected light 55 that travels coaxially with the illuminating light beam 64, passes through the window 39 and part of the reflected light beam 55 passes through the beam splitter 66 into the lens 54 and is launched into the optical fibre 50 at termination unit 46, while the remainder of the reflected light beam 55 is deflected by the beam splitter 66 and deflected by the

mirror 67 back towards the light source. The mirror 67 is merely provided to retain the parallel arrangement between the termination units 46,48 and lenses 54,56.

5 In the second embodiment of the sensor structure 10.2, the illuminating light beam 64 and reflected light beam 55 are coaxial, so that the analysis zone 65 extends across the entire chute 12 – which is beneficial because the analysis zone should preferably extend over as much of the cross-section of the chute as possible, to maximise the likelihood of illuminating falling rocks 11. However, the window 39 in the sensor structure 10.2 should be kept clean and dust free, to prevent light emitted from the lens
10 56 and passed through the beam splitter 66, from being reflected off dust on the window 39 and traveling towards the lens 54 – and ultimately to the spectrometer.

The illustrated embodiments of the invention are intended for obtaining data from a calcined product stream, but the invention can be applied to various other product
15 streams of hot or cold particulate material.

CLAIMS

1. A sensor structure for obtaining data from a moving stream of particulate material, said sensor structure comprising:
 - a light transmitter which is adapted to produce light in a focussed light beam, for illuminating particles in the moving stream; and
 - a light receiver which is adapted to receive light reflected off the illuminated particles and to transmit said light to an optical sensor;wherein the light transmitter and the optical sensor are configured to analyse the light reflected off the illuminated particles or emitted by the illuminated particles, during intervals shorter than a period required for a particle of typical size to pass before the focussed light beam;
 - wherein a focus angle of the light transmitter and an acceptance angle of the light receiver are configured to analyse the light reflected off the illuminated particles or emitted by the illuminated particles, from an analysis zone with a size that is at most as large as a size of a typical particle in the stream of particulate material.
2. The sensor structure according to claim 1, wherein the light source is adapted to produce light continuously and the optical sensor is adapted to analyse the reflected light intermittently.
3. The sensor structure according to claim 1, wherein the light source is adapted to produce flashes of light at timed intervals
4. The sensor structure according to claim 1, wherein the light source is a laser.
5. The sensor structure according to claim 4, wherein the light source is a pulsed laser.

6. The sensor structure according to claim 1, wherein the light receiver has an axis that intersects the focussed light beam at a non-zero, acute angle, so that it is adapted to receive the reflected light along a path which intersects the focussed light beam.
7. The sensor structure according to claim 1, wherein the light receiver has an axis that coincides with the focussed light beam at a zero angle and with no displacement, so that it is adapted to receive the reflected light along at least part of the same path as the focussed light beam.
8. The sensor structure according to claim 1, wherein the focussed light beam is focussed close to infinity.
9. The sensor structure according to claim 1, wherein the acceptance angle of the light receiver is close to zero.
10. The sensor structure according to claim 1, wherein the light transmitter comprises a light source, a first optical fibre and a focussing lens, said first optical fibre having an inlet end and an outlet end and said light transmitter being configured so that light from the light source passes from the inlet end of the first optical fibre to emerge at the outlet end and light emerging from the outlet end passes through the focussing lens to form said focused light beam.
11. The sensor structure according to claim 1, wherein the receiver for reflected light comprises a second optical fibre having an entrance end, and a lens, said lens being adapted to collect light reflected off the illuminated particulate material and launch it into the entrance end of the second optical fibre.

12. The sensor structure according to claim 1, which includes a casing which has an end wall including at least one window, said sensor structure being configured such that the focussed light beam transmitted from the light transmitter and the light reflected off the illuminated particulate material, pass through the window at spaced locations.
13. The sensor structure according to claim 12, which includes two spaced apart windows, configured such that the focussed light beam transmitted from the light transmitter and the light reflected off the illuminated particulate material, pass through different windows.
14. The sensor structure according to claim 12, which includes a manifold defining a passage for a cooling medium, said manifold forming an extension of the casing and being adapted to be fastened to a flow channel down which said particulate material falls.
15. The sensor structure according to claim 14, wherein said end wall of the casing also constitutes an end wall of the manifold.
16. The sensor structure according to claim 14, which includes an air inlet adapted to inject air into the manifold, said sensor structure being configured for the air injected through the air inlet to flow inside the manifold away from the window and towards the flow channel.
17. A method of obtaining data for analytical purposes from a flowing stream of particulate product, said method comprising:
 - illuminating particles in the flowing stream by directing a focussed beam of light at the flowing stream;
 - collecting light reflected from the particles in the flowing stream;

feeding the reflected light that is collected to an optical sensor; and
separately analysing the light reflected off a plurality of individual particles of the illuminated particles, by separately analysing the light reflected of each of the individual particles during an interval that is shorter than the period required for a particle of typical size to pass before the focussed light beam; and
calculating an analysis result from the analysis of the light reflected from the plurality of the individual particles.

18. The method according to claim 17, which includes illuminating the particles at timed intervals by pulsing the focussed beam of light to illuminate the particles in the flowing stream for periods that are shorter than the period required for a particle of typical size to pass before the focussed light beam.
19. The method according to claim 17, which includes illuminating the particles continuously with the focussed light beam and analysing the light reflected of the particles intermittently for periods that are shorter than the period required for a particle of typical size to pass before the focussed light beam.
20. The method according to claim 17, which includes shaping an angle of the focussed light beam to illuminate an area the size of a particle of typical size, at most.
21. The method according to claim 17, which includes shaping an acceptance angle of the light receiver to cover an area the size of a particle of typical size, at most.
22. The method according to claim 17, wherein the angle from which reflected light is collected intersects the focused light beam at a non-zero, acute angle.

23. The method according to claim 17, wherein the flowing stream comprises hot, incandescent particulate product.

