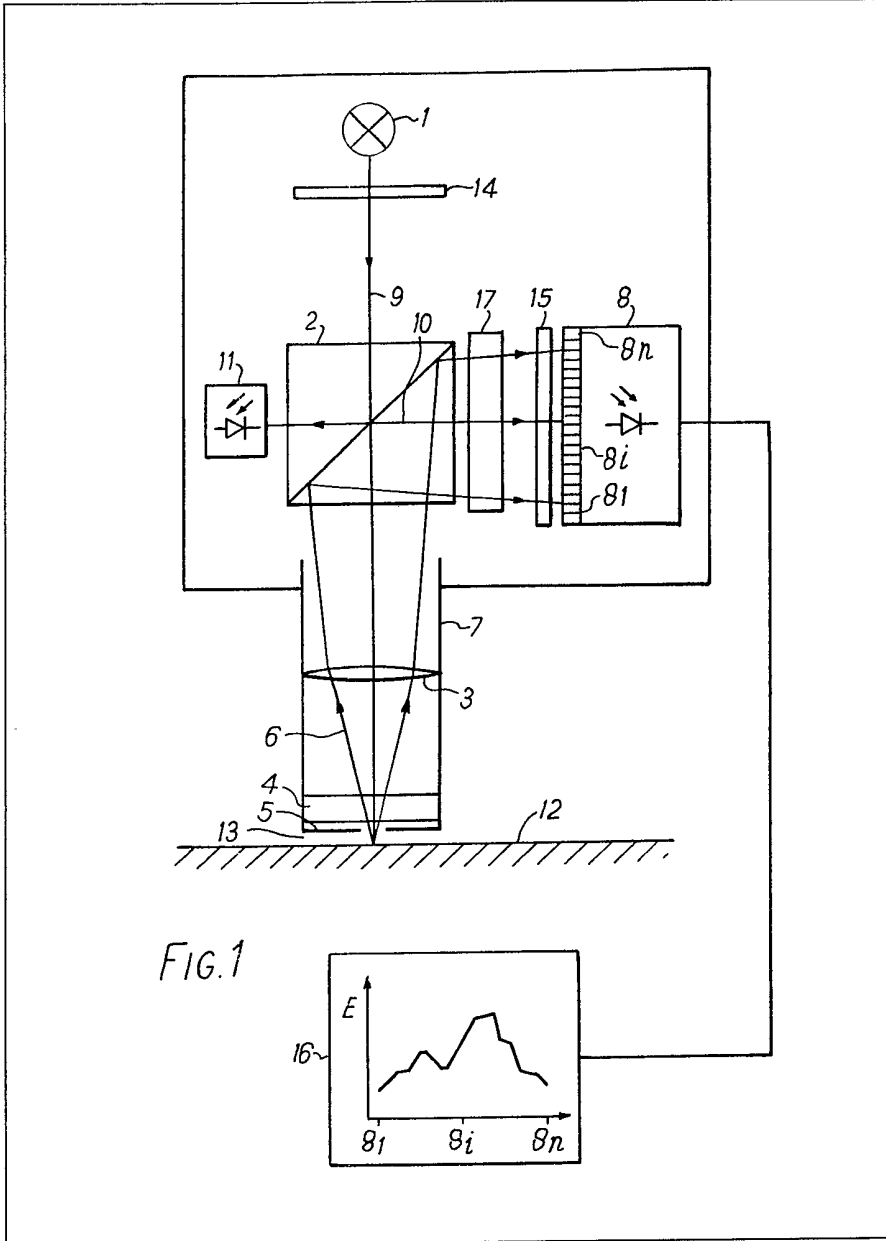


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(54) Measurement of quality of dispersively reflecting surfaces

(57) A parallel beam (9) is directed perpendicularly onto a workpiece surface (12) and the reflected radiation (6)

is measured over a range of solid angles and the distribution is evaluated electronically to give integral characteristic values. Beam splitter 2 directs a small part of the incident beam to a reference detector 11. Lens 3 determines the detected solid angle. Cylindrical lens 17 collects the scattered radiation into a band in which a linear array of photo-detectors 8 is located. Polarized light may be used with polarizers 14 and 15. The light source is preferably pulsed at a fixed frequency.



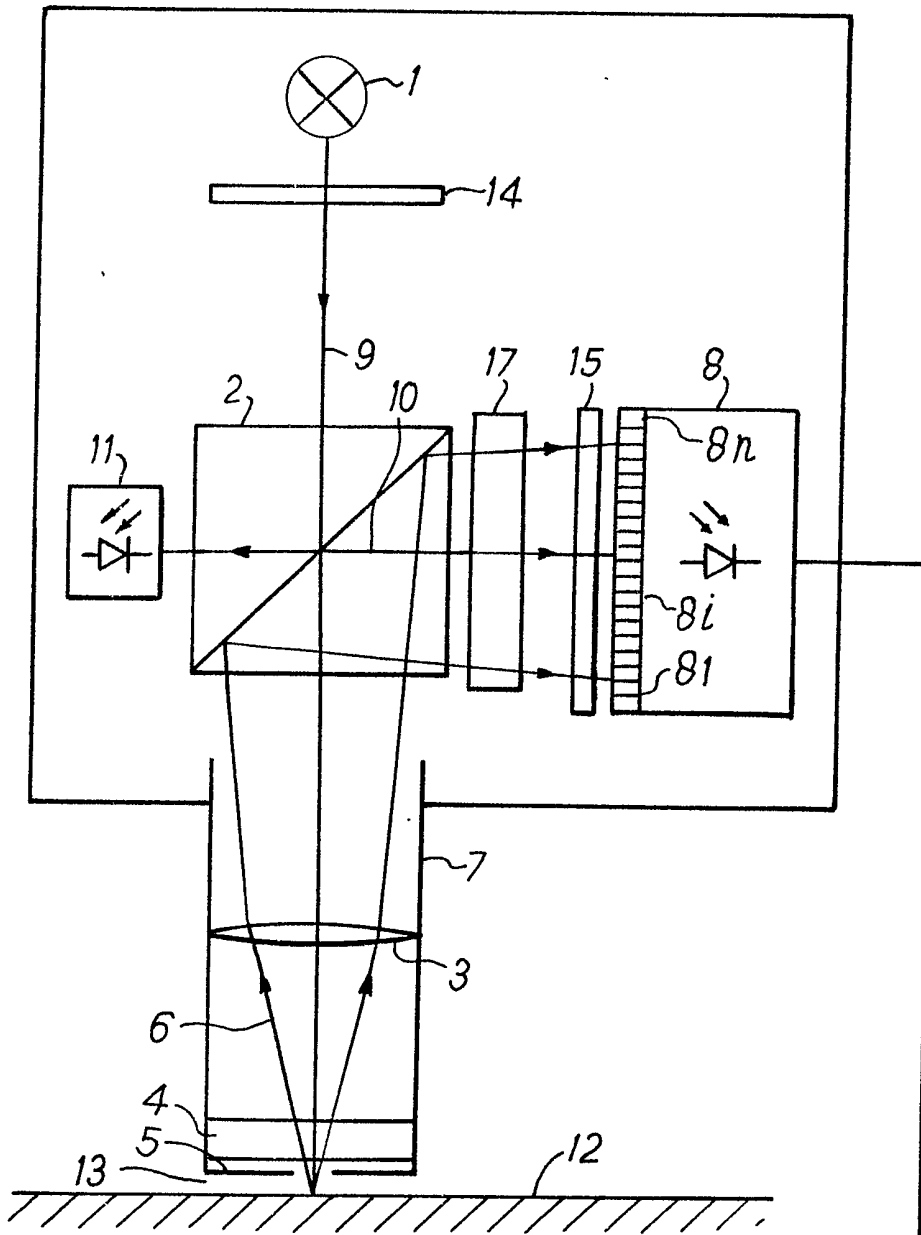
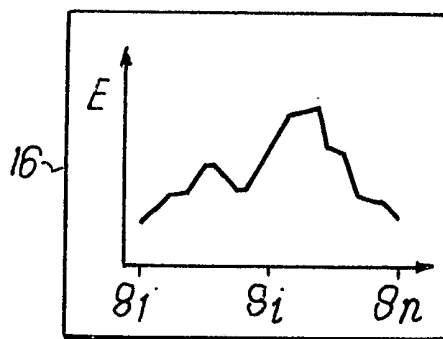


FIG. 1



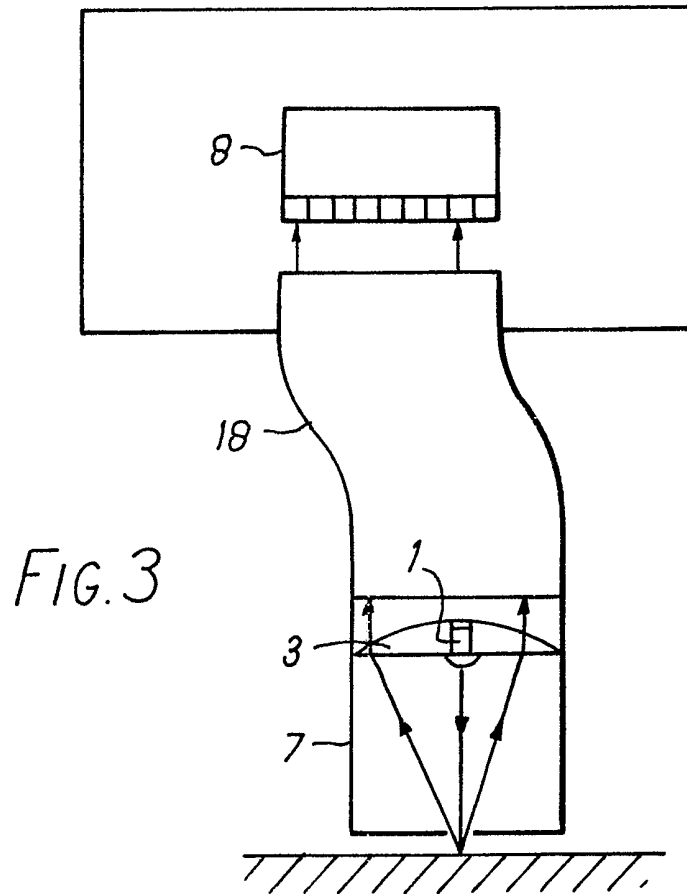
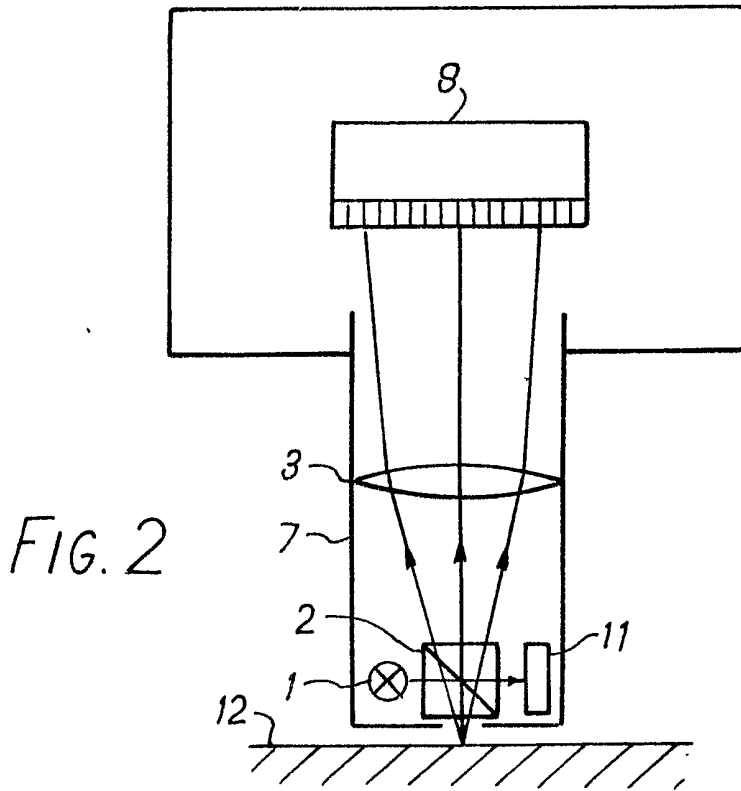


FIG. 4

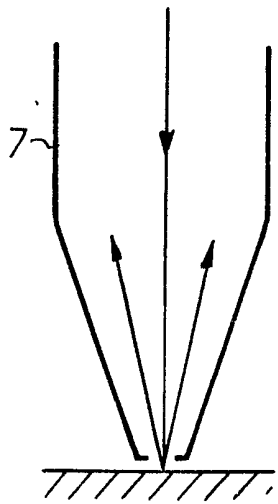


FIG. 5

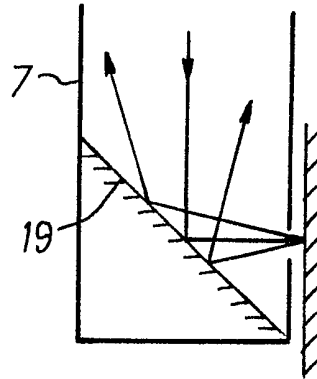


FIG. 6

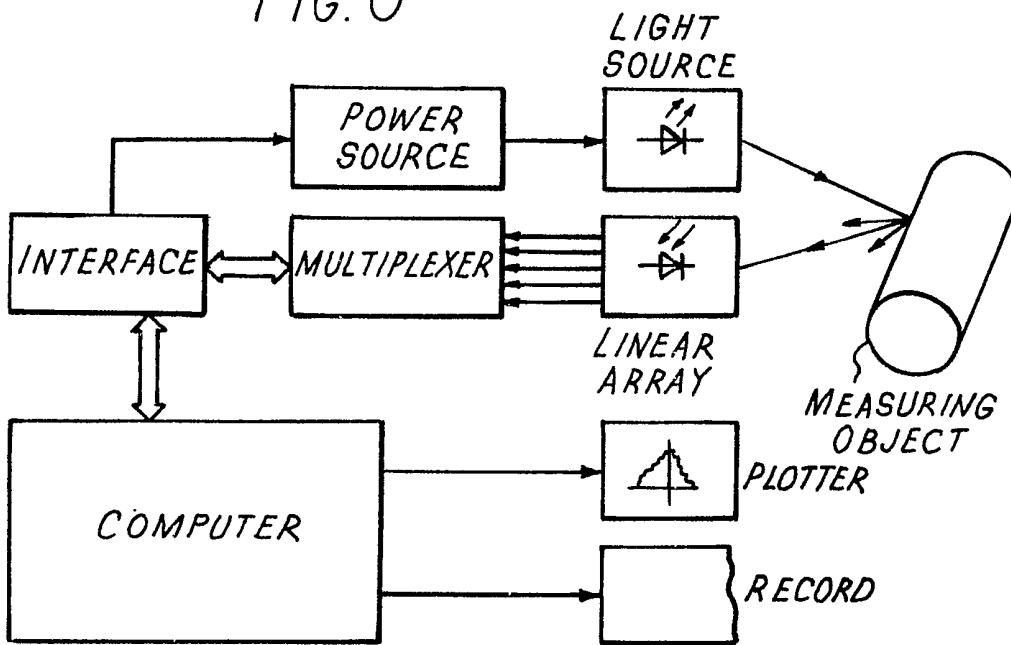
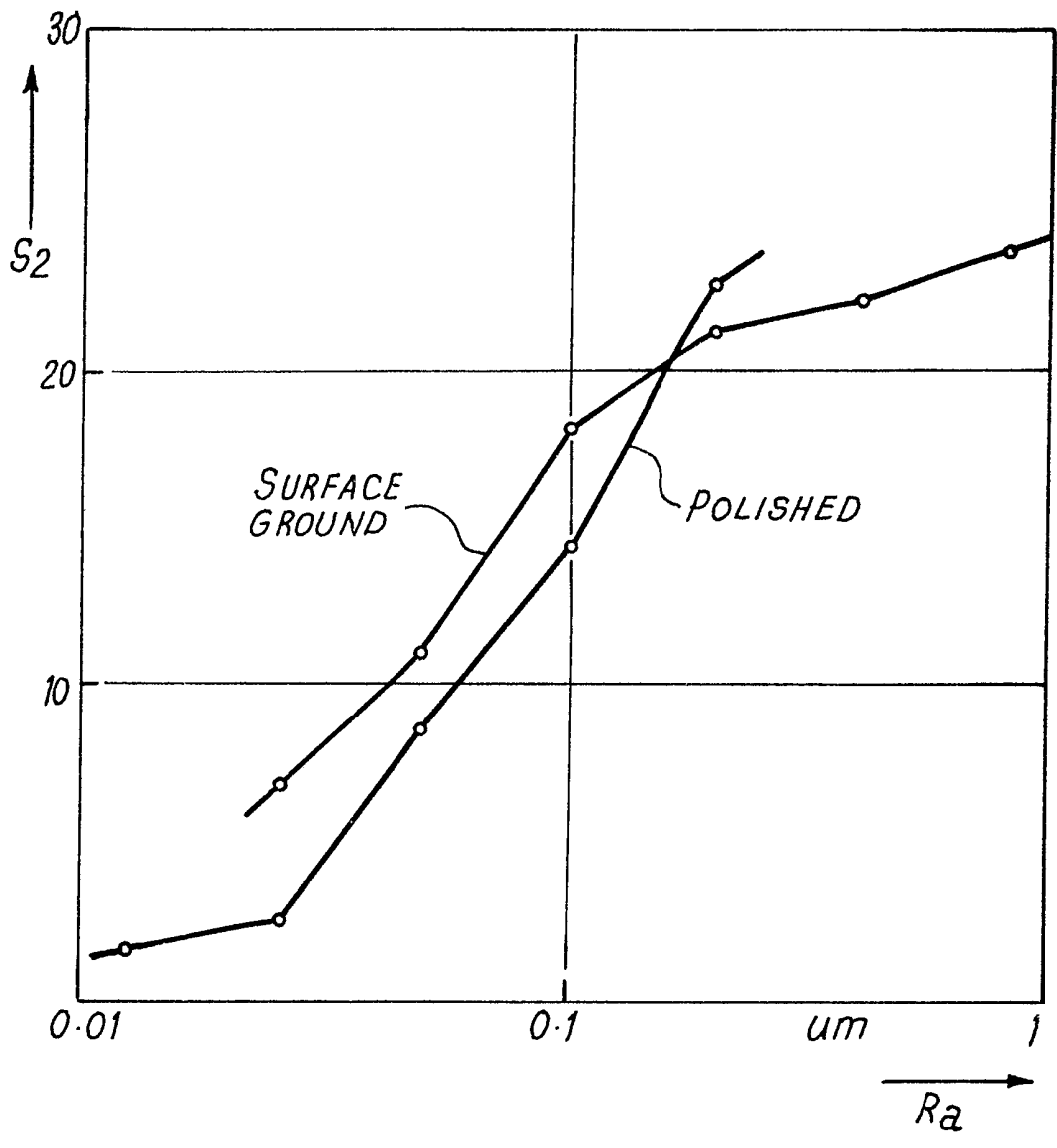


FIG. 7



SPECIFICATION

Measurement of surface quality of dispersively reflecting surfaces

- 5 This invention relates to an optoelectronic measuring method for determining the surface quality of dispersively reflecting surfaces, in particular on metallic work pieces, in which the surface to be examined is illuminated by a generally parallel beam of rays from a light source and the intensity distribution of the reflected radiation is measured and evaluated electronically by photoelectric detectors, and to apparatus for implementing the measuring method. 5
- 10 Measuring methods and apparatus of this type are extremely significant for ensuring the quality of mechanically manufactured work pieces, because the observance of a specific surface quality, for example, on fitting surfaces, close surfaces, friction surfaces and lacquered surfaces is essential for the function of the respective component part. 10
- Various methods and devices are known for measuring the surface quality or surface roughness. Stylus instruments are used very frequently for measuring roughness. They have a small probe in which a diamond needle mechanically traces the surface. The measured values are recorded and/or registered in an amplified manner. These devices have attained a high technical level. A disadvantage is the linear tracing of the surface and the time-consuming measuring procedure which cannot be carried out free of contact and may only be automated with difficulty. 15
- 20 In the book 'Technische Oberflächenkunde', Verlag J. Springer, Berlin 1936, G. Schmaltz describes a measuring method on pages 98 to 99, in which the backscatter indicatrix which is detected using movable photodetectors is evaluated photometrically. Either a factor is used as a measurement for the surface quality, which factor describes the approximation of the scattered light curve to a Gaussian distribution, or the half-power angle is used, at which the radiation intensity is reduced to half the intensity which is radiated at the specular reflection angle. This method starts out in a restrictive manner from a Gaussian distribution of the scattered light curve, or only two measured values for characterising the surface quality are used from the complete scatter curve. Apart from the fact that the pre-requisite of a Gaussian distribution of the scattered light curve is not provided for most surface structures, the evaluation which is based on only two measuring points leads to inaccurate measuring results. 20
- 25 A measuring apparatus is known from German Auslegeschrift No. 2,260,090 which uses the half-power width of the scattered light distribution about the specular reflection angle of between 60 and 85° angle of incidence as a measurement for the roughness. This measurement is formed from a total of three measuring points of the scattered light distribution, that is, the measured value at the peak of the curve and the respective half-values. In this case, there is a disadvantage in that the half-width value is not clearly defined on flat or multiple-peak distribution curves, as occurs in technical roughnesses and it is an unreliable measurement in the statistical sense. Chance fluctuations in the measured values, in particular in the maximum value which represents the reference value have a direct effect on the measuring result. The flat incidence of light necessary for measuring renders the measuring arrangement sensitive to changes in spacing and due to its large dimensions, the measuring apparatus may only be used when there is enough space and time available for the complicated handling. 25
- 30 Furthermore, a method is known from the publication by F. Piwonka und Th. Gast in "Technisches Messen" (1979) 12, P. 451-458 in which rotating photoreceivers are used to record the backscatter indicatrix and the depth of roughness is calculated therefrom. This method may only be applied to surfaces which are machined periodically, for example on a rotary machine, because the groove width of the rough grooved surface must be known. The measuring range of this arrangement only covers the coarse range of surface roughness. 30
- 35 Another method for measuring roughness is known from Germany Patent No. 2,241,617 which operates with a laser. In this method, the flat measuring sample is rotated mechanically and the angular-dependent light reflected back in the direction of incidence is measured. The probability distribution of the partial derivatives of the roughness profile is calculated from the light distribution. The physical boundary conditions to be observed in this method and the necessary relative movement of the measuring apparatus and of the object to be measured considerably restrict the area of use. 35
- 40 Furthermore, methods for measuring roughness are known from the literature which evaluate the "speckle" pattern in the scatter field of the reflected light. For this purpose, an illumination apparatus is necessary which meets certain coherency conditions, for example, a laser. 40
- 45 An object of the present invention is to provide a measuring method and measuring apparatus which allow a surface quality to be determined more accurately using simple and manageable devices. 45
- Using the measuring apparatus, measurements on flat, convex and concave measuring surfaces and at difficult measuring points such as on bevels, in grooves and bores may be carried out free of contact or with gentle contact in a rapid measuring sequence. The measuring apparatus may be operated manually and it may also be easily incorporated into automatic apparatus, in which case it is unnecessary to work with coherent light. 50
- 50 Based on the initially-mentioned measuring method, this object is achieved according to the present invention in that a beam of rays is directed generally perpendicularly onto a surface to be examined and the spatially distributed reflected radiation coming out from the illuminated surface section (measuring spot) is 50
- 60 65

detected by photoelectric detectors at a solid angle which is adapted to the spread to be expected of the beam as a result of the scatter reflection and that integral characteristic values are formed from all of the measured values established by the detectors as a measurement for the surface quality. Further developments of the measuring method according to the present invention and of the apparatus for implementing the method are specified in the subclaims.

The basic concept of the present invention essentially lies in detecting the scattered radiation reflected by the measuring spot using a measuring tube at a solid angle which is adapted to the scatter and thus to the expected quality range of the surface to be examined and in forming integral characteristic values S_x from the intensity values measured with detectors in the manner of power moments known from mechanics and statistics, which characteristic values S_x are used as a measurement for the surface quality.

The following equations are used to form the characteristic values.

$$(a) \quad S_x = \sum_{i=1}^n |w_i - \bar{w}|^x \cdot p_i \quad \text{where } x = 1 \text{ or } 2$$

$$(b) \quad \bar{w} = \sum_{i=1}^n w_i \cdot p_i$$

$$(c) \quad p_i = \frac{D_i \cdot g_i}{\sum_{i=1}^n D_i \cdot g_i}$$

The references in the equations represent the following:

- w_i the angle of the scattered radiation detected by the respective detector i
- n the number of detectors used for evaluation
- \bar{w} the average from values p_i and w_i
- p_i measurement signal D_i standardized according to the equation (c)
- g_i correction factor for the measurement signal D_i .

In the method according to the present invention, values p_i standardized according to the equation (c) are obtained from the measured signals of the detectors n which are preferably positioned in a row, taking into account the correction factors g_i . In contrast to the known methods and arrangements described above, the measurement signals of all the detectors recording the reflected radiation enter into the evaluation. Due to the formation of the quotient p_i , only the scatter characteristics of the surface structure are evaluated and the material-conditioned spectral reflection coefficients remain without influence on the measuring result. An average \bar{w} is calculated from the values p_i and the values w_i . The characteristic values S_1 or S_2 are formed last of all. The quadratic scatter characteristic value S_2 is the statistically reliable value. On the other hand, it is easier to calculate the characteristic value S_1 .

The correction factors g_i are to balance manufacturing tolerances in the electrical and optical characteristic values of the construction elements used and to correct the changes in the scattered light distribution determined in a geometrically-optical manner by optical construction elements.

For this purpose, the factors lying between 0 and 1 are determined in a measuring procedure with a comparative surface of known scatter.

Moreover, it is also possible by approximation of these factors to influence the characteristic line path of S_1 or S_2 over a greater range of the surface quality by a different weighting of the scattered light curve, for example in order to carry out a linearisation, and to emphasize or suppress specific parts of the scattered light curve, for example, in order to evaluate separately scattered light or regularly reflected light.

The advantages of the present invention are mainly found in the following facts:

- the surface quality is determined as an average over a measuring spot;
- integral characteristic values S_1 or S_2 are formed which allow a reliable and accurate statement even in the case of randomly formed scattered light curves, and the type of distribution, for example Gaussian distribution, does not have to be known;
- the characteristic value formation include all detectors, and chance fluctuations in the scattered light curve, as caused by alignment errors or statistical irregularities of the surface, are averaged out;
- the integral characteristic values are invariant to a swing in the scattered light distribution in the measuring plane;

- optical quality features of the surface, such as, for example, the scatter behaviour and structural features are exactly described by the characteristic values S_1 or S_2 ;
- there is a close, very effectively reproducible connection between the characteristic values S_1 or S_2 and standardized roughness characteristic quantities when the fabrication conditions are known;
- 5 - by adapting the solid angle detected by the measuring apparatus to the angle of the scattered radiation, a large measuring range is achieved which extends from $R_a > 0.01 \mu\text{m}$ to $R_a < 10 \mu\text{m}$, oriented at the average roughness value R_a ;
- separate determination of transverse and longitudinal roughness is possible by rotating the measuring plane;
- 10 - the measuring arrangement is insensitive to changes in spacing due to the generally perpendicular irradiation;
- the measurement may be carried out with gentle contact or free of contact manually or automatically even at difficultly accessible measuring points; and
- measurements on stationary and on moving surfaces are possible.
- 15 The characteristic values S_1 or S_2 may be determined in an electronically analog or digital manner. It is preferred to calculate the characteristic value in a computer because this easily allows measured data to be stored, and allows an interactive operation control and a comprehensive documentation of the measuring results. 15
- In order to adjust a specific characteristic line path of the characteristic values S_1 or S_2 over a range of the surface quality, the characteristic values are to be multiplied in the computer with a scale factor and/or powers 20 of the characteristic values are to be used. Standardized roughness characteristic quantities such as the average roughness R_a or the averaged roughness depth R_z are determined indirectly via measuring procedures. Surfaces of known roughness are measured optically and the characteristic quantities S_1 or S_2 are related to stylus characteristic quantities. The relevant characteristic line is stored in a computer. In order 25 to achieve a high measuring accuracy, it is appropriate to measure and store several characteristic lines corresponding to the conventional processing methods. 25
- Another possibility is to vary the wave length range of the measured radiation in order to adjust different scatter angle ranges. The scattering on surfaces of a specific roughness is greater with short wave lengths, for example UV light, compared to long wave lengths, for example IR light. The radiation used does not have 30 to be monochromatic, but it may extend over a greater wave length range, for example, 100 nm. 30
- Another possibility is to use polarized measured radiation. During the reflection of polarized radiation, rough surfaces exhibit a behaviour which differs from smooth surfaces and from which the surface quality may be deduced by considering the orientation of the polarisation plane of the radiation to the structure of the surface. Thus, the characteristic values S_1 or S_2 may be used as a measurement for the surface quality 35 from the polarisation condition of the radiation within the reflected radiation beam. 35
- The invention is described in the following with reference to embodiments of the measuring apparatus. The drawings illustrate schematic views.
- Figure 1* illustrates a scattered light measuring apparatus according to the present invention,
- Figure 2* illustrates a view of a measuring apparatus with a beam source in a measuring tube,
- 40 *Figure 3* illustrates a measuring apparatus with a flexible light guide, 40
- Figure 4* illustrates a measuring tube having a conical point,
- Figure 5* illustrates a measuring tube having a lateral beam outlet,
- Figure 6* illustrates a block diagram of the measuring system with a computer for processing the measured values, and
- 45 *Figure 7* graphically illustrates the dependence of the characteristic value S_2 on the surface quality of different samples of surfaces. 45
- In the measuring apparatus according to *Figure 1*, a beam source 1 is provided, for example, a diode emitting infrared light having a glass lens which is attached thereon and whose concentrated, generally parallel radiation 9 passes through a beam splitter 2, a lens system 3 and a plane-parallel glass plate 4. The 50 measuring spot is restricted by a circular diaphragm 5 to about from 1 to 3 mm in diameter. The system is completely encapsulated by the glass plate 4. The direction of the radiation 6 reflected by the surface 12 is 50 changed by the refractive power of a lens system 3 and the radiation 6 passes back through the beam splitter which outwardly reflects as large a partial flux as possible to the photoelectric detectors 8. Photodiodes or pyroelectric detectors may be used individually or in the embodiments as a linear array or a matrix array, as 55 the detectors 8₁, 8₂ to 8_n. The detectors convert the radiation into electrical signals which are further processed in analog or digital manner, having been filtered and amplified, such that they state the scatter characteristic values S_1 or S_2 as a measurement for the surface quality. The path of the intensity of irradiation E is indicated on a screen 16, this path being measured by the detectors 8₁ to 8_n. In order to improve the 60 disturbance signal-to-noise ratio, the detectors are provided with an optical filter which narrows the spectral range of reception to the wave length range of the beam source. 60
- A further improvement arises from working in variable light operation. For this purpose, the light of the beam source is pulsed electrically or optically with a specific frequency and the measurement signal is evaluated in a frequency-selective manner. The measuring tube 7 determines the solid angle with its dimensions, in particular its length and with the lens system 3 contained therein and with the glass plate 4, 65 the reflected radiation being supplied to the detectors 8₁ to 8_n at this solid angle. In the simplest case, the 65

lens system 3 may be omitted. The solid angle then results from the geometrical data of the measuring apparatus, substantially from the aperture angle of the detector row 8. Lens systems having a positive focal distance enlarge the solid angle, dispersing lenses narrow this angle.

In the method according to the present invention, it is unnecessary to position the detectors in the focal plane of the lens system or to carry out a real representation of the illuminated surface section, as a result of which, advantages are provided in the dimensioning of the measuring tube.

Several measuring tubes which may be mutually exchanged and which differ in their optical characteristic data are provided for each measuring apparatus. This allows an adaption to the scatter angle range which is to be expected during a measurement and which results from the range of the surface quality of the surface to be examined. The range of the surface quality is provided by the surface processing method which takes place before measuring, for example, fine rotation, surface grinding or polishing. The respective appropriate measuring tube is selected based thereon.

According to Figure 1, a cylinder lens 17 is inserted into the beam path of the scattered light. This lens collects the spatially distributed scattered radiation into a band of light in the measuring plane which is defined by the centre beams 9 and 10 and in which is located the row 8 of detectors. As a result of this measure, the disturbing influence of the beam scatter on convex surfaces is reduced and the useful radiation flux is increased. This cylinder lens may be integrated into the lens system 3. It is even advantageous to construct the lens system 3 from a system of crossed cylinder lenses, the focal distance of which is selected such that the scattered radiation is detected in one plane at the angle which is most favourable for determining the surface quality and in the other plane, the reflected radiation is collected into a band of light in which the detectors 8 are located. In the case of lenses having a high refractive power, it is appropriate to flatten them in the centre, so that the incident beam remains unchanged, while the dispersively reflected radiation is refracted by the curved lens surfaces. This optical intervention is compensated during electronic processing of the measured values.

Another photoelectric detector 11 (reference detector) measures the part, branched off by the beam splitter 2, of the beam 9 coming from the beam source 1. The beam intensity fluctuations thereof are compensated in the measured data processing operation via a quotient and/or subtraction circuit. The measurement may take place with slight contact in that the small manageable scattered light measuring apparatus is positioned with the measuring tube 7 generally perpendicularly on the surface 12 to be measured. Since the supporting surface of the measuring tube is relatively large and only small forces are prevalent, the surface to be measured is substantially prevented from being damaged. For measuring very sensitive surfaces, the supporting surface of the measuring tube should be made of a non-rigid material, for example, a plastics material. Contact-less measurement is achieved by adjusting a small measuring spacing 13 and thus, a measurement is also possible on moving surfaces. This type of operation may also be advantageously applied in automatic apparatus.

In order to determine the surface characteristic quantities, termed transverse or longitudinal roughness in roughness measuring technology on directional rough structures, for example, on grooved roughness, the measuring device may be oriented with its measuring plane transversely or longitudinally to the direction of the grooves. Another possibility of measuring the direction-dependent scatter characteristics of a surface without rotating the measuring device about 90° during this measurement lies in a matrix arrangement consisting of several rows of detectors or in an arrangement of crossed rows of detectors. In the latter case, a second row of detectors is positioned perpendicularly to the row 8 of detectors and this second row detects the reflected radiation perpendicularly to the measuring plane. A possibility of expanding the measuring range of the apparatus provided by the geometry and the optical system of the measuring tubes consists in changing the wave length of the radiation used. For this purpose, either the light of the beam source 1 is monochromatic, or a filter is used to screen a specific wave length range from a beam source which has a broad spectrum.

Another possibility is to measure scattered light using polarized radiation. For this purpose, a polarisation filter 14 is provided in the arrangement to produce polarized radiation and a polarisation filter 15 is also provided to analyse the reflected radiation.

According to Figure 2, the measuring apparatus according to Figure 1 is modified such that the beam source 1, for example a small semiconductor beam source, is located in the measuring tube 7. The advantage of this arrangement is the fact that the beam of rays from the beam source 1 does not enter via the lens system 3, but the scattered radiation is detected by the lens system. As a result of this, the scattered radiation may be detected in a large solid angle which is necessary for the coarse roughness range. In this arrangement, the beam splitter 2 is positioned between the beam source 1 and the reference diode 11, while the row 8 of detectors is located in the housing of the apparatus.

Where there are unfavourable spatial conditions, it is advantageous to use a light guide, for example, in order to measure inside surfaces of work pieces or inside the processing machine using the apparatus. An ordered optical-fibre bundle may be used as a light guide, the cross section of which may be rectangular or circular and/or fibre optical cross-section transducers may be used. In the arrangement according to Figure 1, the light guide is preferably inserted between the measuring tube 7 and the beam splitter 2 and it guides both the incident radiation as well as the reflected radiation. A light guide may also be used in the arrangement according to Figure 2 for guiding the reflected radiation. It is appropriately positioned between the measuring tube 7 and the row 8 of detectors.

Figure 3 illustrates an arrangement in which the beam source 1 is again located in the measuring tube 7 and is inserted directly into the lens system 3. Since the beam splitter has been omitted, the useful radiation of the beam source is increased. In this case, the reflected light flux is supplied to the detectors 8 via a flexible light guide 18. In order to illuminate the surface section to be measured, another light guide having a small diameter may be used which is positioned concentrically to the light guide 18. This additional light guide is to be provided separately from the light guide 18 in the housing of the apparatus and it allows the light of a high power beam source to be supplied to the measuring point.

Figure 4 illustrates an embodiment of a measuring tube having a conical measuring point. This shape of the measuring tube is suitable for spatially confined measuring points.

Figure 5 schematically illustrates another embodiment of the measuring tube, in which the light escapes at the side through a deflecting mirror 19, which is advantageous, for example, for measurements in a bore or in a groove of a work piece.

Figure 6 illustrates a block diagram of the measuring system. A computer is used to process the measured values. Several scattered light sensors may be connected to this basic electronic device. The measuring procedure is clarified in the block diagram. A light-emitting diode is fed by a power source and it illuminates the surface to be measured of the measuring object. The photodiodes of a linear array convert the reflected light flow into electrical signals which are supplied to the electronics (shown with interface) via multiplexers and controlled by the computer. The signals are filtered in the electronics, amplified and are available to the computer for further processing as digital values after an analog-digital conversion. The result of the measurements is recorded or presented graphically on a screen or on a plotter.

Characteristic curves are shown in Figure 7 which have been produced from comparative measurements of the method according to the present invention with stylus measurements on surface-ground and polished surface samples. The scatter characteristic value S_2 is dimensionless and is plotted, multiplied with a scale factor against the average roughness value R_a which was measured using a stylus device.

The apparatus which has been described is provided for determining the surface quality of flat, concave or convex metallic surfaces. In addition thereto, it is possible using this measuring apparatus to also determine the surface quality of parts made of other materials, for example, semiconductor materials, plastics and porcelain.

A measuring method similar to the one according to the present invention may also be used for determining the surface quality or the scatter behaviour of work pieces made of transparent material, for example, glass. In this method, the work piece to be examined is illuminated from the work piece surface opposite the measuring head and the penetrating light is spread and scattered by the irregular structures. The scattered light distribution is then generally measured in the same manner as described above for the reflected scattered light.

CLAIMS

1. An optoelectronic measuring method for determining the surface quality of dispersively reflecting surfaces, in particular the surface of metallic work pieces, in which the surface to be examined is illuminated by a generally parallel beam of a light source and the intensity distribution of the reflected radiation is measured and evaluated electronically by photoelectric detectors, characterised in that the beam is directed generally perpendicularly onto the surface to be examined and the spatially distributed and reflected radiation coming out from the illuminated surface section (measuring spot) is detected by the photoelectric detectors at a solid angle which is adapted to the spread of the beam to be expected due to scatter reflection and that integral characteristic values are formed from all of the measured values established by the detectors as a measurement for the surface quality.

2. An optoelectronic measuring method according to claim 1, characterised in that the integral characteristic values S_1 or S_2 are formed from the measured values of the photoelectric detectors as a measurement for the surface quality according to the following equations:

$$(a) \quad S_x = \sum_{i=1}^n |w_i - \bar{w}|^x \cdot p_i \quad \text{where } x = 1 \text{ or } 2$$

$$(b) \quad \bar{w} = \sum_{i=1}^n w_i \cdot p_i$$

$$(c) \quad p_i = \frac{D_i \cdot \varepsilon_i}{\sum_{i=1}^n D_i \cdot \varepsilon_i}$$

and the references in these equations denote the following:

- w_i the angle of the scattered radiation detected by the respective detector i
 n the number of detectors used for evaluation
 5 \bar{w} the average from the values p_i and w_i 5
 p_i measurement signal D_i standardized according to the equation (c)
 g_i correction factor for the measurement signal D_i .
3. An optoelectronic measuring method according to claim 2, characterised in that the tolerances of the
 10 optical and electronic construction elements are balanced by the correction factors g_i and/or the measuring
 signals of the individual detectors are weighted. 10
4. An optoelectronic measuring method according to claim 1 to 3, characterised in that the scatter angle
 of the reflected radiation is varied by changing the wave length of the measured radiation.
5. An optoelectronic measuring method according to claim 1 to 4, characterised in that the incident beam
 15 is polarized for the assessment of surface structures. 15
6. An optoelectronic measuring method according to claim 5, characterised in that the polarisation
 condition of the reflected scattered radiation is determined, for example, by an analyser.
7. An optoelectronic measuring method according to claim 1 to 6, characterised in that the
 directional-dependence of the reflection behaviour of surfaces having a directed (anisotropic) rough
 20 structure is established by rotating the measuring plane. 20
8. An optoelectronic measuring method according to claim 1 to 7, charcterised in that some of the
 incident radiation is supplied to a reference photodetector and fluctuations in the beam intensity are
 compensated by the output signal of the photodetector via an analog or digital circuit.
9. An apparatus for implementing the measuring method according to claims 1 to 8, characterised by an
 25 exchangeable measuring tube (7) which may be positioned on the surface (12) to be examined or may be
 fixed at a small spacing (13) from this surface (12), having a diaphragm (5), and the solid angle of the
 scattered radiation which may be detected by the detector (8) is determined by the length and/or optical
 characteristics of the tube (7). 25
10. A measuring apparatus according to claim 9, characterised in that the measuring tube (7) contains a
 30 lens system (3). 30
11. A measuring apparatus according to claim 9 or 10, characterised by a cylinder lens (17) which collects
 the scattered radiation into a band of light, in which the photoelectric detectors (8) positioned in a row, for
 example, as a linear photo array are located.
12. A measuring apparatus according to claim 10, characterised in that the lens system (3) is formed from
 35 crossed cylinder lenses, one of which detects the scattered radiation at the respectively necessary solid
 angle and the other collects the scattered radiation into a band of light in which the row (8) of detectors is
 positioned. 35
13. A measuring apparatus according to claim 9 to 12, characterised in that the measuring tube (7) is
 tightly sealed off by a plane-parallel glass plate (4) in the region of the diaphragm (5).
- 40 14. A measuring apparatus according to claim 9 to 13, characterised in that a beam splitter (2) is 40
 positioned in the incident beam of rays (9) and a small part of the incident beam is deflected by the splitter (2)
 to a reference detector (11) and as large a part as possible of the reflected radiation is deflected to the row (8)
 of measuring detectors.
15. A measuring apparatus according to claims 10 to 14, characterised in that the lenses of the lens
 45 system (3) are flattened in their centre, so that the incident beam of rays is unchanged while passing through 45
 the system, but the dispersively reflected radiation is refracted by the lenses.
16. A measuring apparatus according to claims 10 to 14, characterised in that the beam source (1) is very
 small, preferably being designed as a semiconductor beam source, and is positioned in the measuring tube
 (7) between the lens system (3) and the diaphragm (5).
- 50 17. A measuring apparatus according to claim 16, characterised in that the light source (1) is integrated 50
 into the lens system (3).
18. A measuring apparatus according to claim 9 to 15, characterised in that a light guide is preferably
 provided between the measuring tube (7) and the row (8) of detectors for guiding the incident beam and/or
 the reflected radiation.