

DESCRIPTION

THREE-DIMENSIONAL SURFACE ROUGHNESS EVALUATING DEVICE, THREE-
DIMENSIONAL SURFACE ROUGHNESS EVALUATING METHOD, THREE-
5 DIMENSIONAL SURFACE ROUGHNESS DATA ACQUIRING DEVICE, AND
THREE-DIMENSIONAL SURFACE ROUGHNESS DATA ACQUIRING METHOD

Technical Field

[0001]

10 The present invention relates to a three-dimensional
surface roughness evaluating device which acquires surface
roughness parameters regarding three-dimensional surface
roughness of an untransportable object, structure, or the like.
Particularly, the present invention relates to a three-
15 dimensional surface roughness evaluating device, a three-
dimensional surface roughness evaluating method, a three-
dimensional surface roughness data acquiring device, and a
three-dimensional surface roughness data acquiring method
which enable surface roughness parameters to be acquired
20 quickly, successively, in large quantities, and directly.

Background Art

[0002]

The surface roughness shape of an object is important in recognizing frictional properties of the surface thereof. In recent years, as shown in Non-Patent Document 1, there has been shown the importance of the measurement of not only roughness
5 height but also a shape parameter including a wavelength or the like, for the recognition of water-flow frictional properties of an object surface.

[0003]

Non-Patent Document 1 describes an evaluation regarding
10 surface roughness (coating film surface roughness) of a ship hull, and shows that a sufficient number of shape parameters need to be measured within a considerably wide area in order to evaluate surface roughness of an untransportable object or structure, such as a ship hull.

15 [0004]

Furthermore, there is pointed out a problem in which, when a "BSRA hull roughness analyzer" that is a conventional roughness measurement instrument is used, precise measurement and a parameter analysis of ship hull surface roughness are
20 impossible. In order to solve the problem, according to Non-Patent Document 1, surface roughness of a ship hull is measured by creating a roughness replica of the surface of the ship hull by use of thermoplastic resin, and performing a surface

analysis of the roughness replica by a point-like laser displacement meter mounted on an X-Y stage in a laboratory.

[0005]

Patent Document 1 suggests a shaded image recording
5 device used as a non-contact roughness measurement device for
an untransportable object, structure, or the like.

Prior Art Documents

Patent Documents

10 [0006]

Patent Document 1: Japanese Unexamined Patent Application
Publication No. S61-292509

Non-Patent Documents

15 [0007]

Non-Patent Document 1: Hirohisa Mieno, Hiroshi Masuda,
"Friction Increase due to Roughness of Ship Hull Paint -
Reduction of Hull Resistance by Painting on Outer Plate of Ship
Bottom", journal of the Japan Institution of Marine Engineering,
20 Vol.48, No.3 (2013), pp.300-307

Summary of Invention

Technical Problem

[0008]

The technique disclosed in Non-Patent Document 1 is limited in the area that can be replicated by a roughness replica, and therefore has a problem that excessive labor is required to evaluate a wide area. Moreover, the technique
5 disclosed in Patent Document 1 measures roughness on the basis of a shaded image taken by applying a light source, and is therefore not suited to accurately measuring a shape parameter of a relatively smooth surface.

[0009]

10 Furthermore, in the measurement of a roughness parameter of micrometer-order minute roughness, the most accurate measurement can be performed by causing a laser-type optical displacement meter to traverse by an X-Y stage or the like and thus ensuring mechanical precision.

15 [0010]

However, when it is necessary to measure a wide area, for example, a ship hull by such a method, a traversing device is increased in size and weight, which makes difficult on-site handling including processing, painting, and others. Moreover,
20 despite a size increase, there is a technical limitation under which the operation range of the traversing device and measurement area are limited.

[0011]

Still further, when an X-Y stage is used, it is necessary to use a precision stage and a stepping motor in order to precisely actuate the X-Y stage in an X-Y direction. In addition, it is also necessary to provide an X-Y stage controller which controls such an X-Y stage, a controller for a laser displacement meter, and the like. This leads to the increase of weight and power consumption as a measurement device, and is therefore not suited to carrying the measurement device.

10 [0012]

In view of such circumstances, the present invention is intended to provide a three-dimensional surface roughness evaluating device, a three-dimensional surface roughness evaluating method, a three-dimensional surface roughness data acquiring device, and a three-dimensional surface roughness data acquiring method which enable surface roughness parameters regarding three-dimensional surface roughness of an untransportable object, structure, or the like to be acquired quickly, successively, in large quantities, and directly.

20

Solving to Problem

[0013]

The present invention has been made to solve the above-described problem in the conventional technique, and a three-

dimensional surface roughness evaluating device according to the present invention includes:

a two-dimensional laser displacement meter;

a movement mechanism which moves the two-dimensional
5 laser displacement meter in an X-axis direction;

a movement distance measuring device which measures a movement distance of the two-dimensional laser displacement meter in the X-axis direction; and

a calculating device which generates three-dimensional
10 surface roughness data of a measurement target on the basis of displacement data acquired by the two-dimensional laser displacement meter and movement distance data acquired by the movement distance measuring device, wherein

the two-dimensional laser displacement meter is disposed
15 so that the width direction of the two-dimensional laser displacement meter coincides with a Y-axis direction, to be able to measure displacement data of coordinates in the Y-axis direction at fixed intervals,

the measuring width of the two-dimensional laser
20 displacement meter is at least two or more times mean width of the roughness profile elements R_{Sm} of elements of the measurement target, and

the calculating device is configured to

generate reference surface data of each coordinate by averaging in the Y-axis direction the displacement data acquired at fixed intervals in the X-axis direction by the two-dimensional laser displacement meter, and

5 generate three-dimensional surface roughness data of the measurement target by subtracting the reference surface data of each coordinate from the displacement data of each X-Y plane coordinate.

[0014]

10 In such a three-dimensional surface roughness evaluating device, the movement distance measuring device can be a device which reads a movement distance with a scale sensor by a circular scale that operates together with the movement mechanism, or a device which reads the number of revolutions
15 by a rotary encoder and computes a movement distance.

[0015]

In addition, it is also possible to further provide a transportable battery.

[0016]

20 Furthermore, a three-dimensional surface roughness evaluating method according to the present invention generates three-dimensional surface roughness data of a measurement target, and includes:

acquiring displacement data by measuring a displacement in an X-axis direction at fixed intervals by a two-dimensional laser displacement meter having a measuring width that is at least two or more times mean width of the roughness profile elements RSm of elements of a measurement target;

averaging the displacement data in the Y-axis direction and thus generating reference surface data of each coordinate; and

subtracting the reference surface data of each coordinate from the displacement data of each X-Y plane coordinate, and thus generating three-dimensional surface roughness data of the measurement target.

[0017]

Still further, a three-dimensional surface roughness data acquiring device according to the present invention includes:

a two-dimensional laser displacement meter;

a movement mechanism which moves the two-dimensional laser displacement meter in an X-axis direction; and

a movement distance measuring device which measures a movement distance of the two-dimensional laser displacement meter in the X-axis direction, wherein

the two-dimensional laser displacement meter is disposed so that the width direction of the two-dimensional laser displacement meter coincides with a Y-axis direction, to be

able to measure displacement data of coordinates in the Y-axis direction at fixed intervals, and

the measuring width of the two-dimensional laser displacement meter is at least two or more times mean width of
5 the roughness profile elements R_{Sm} of elements of a measurement target.

[0018]

In such a three-dimensional surface roughness data acquiring device, the movement distance measuring device can
10 be a device which reads a movement distance with a scale sensor by a circular scale that operates together with the movement mechanism, or a device which reads the number of revolutions by a rotary encoder and computes a movement distance.

[0019]

15 In addition, it is also possible to further provide a transportable battery.

[0020]

Further yet, a three-dimensional surface roughness data acquiring method according to the present invention acquires
20 three-dimensional surface roughness data of a measurement target, and includes:

acquiring displacement data by measuring a displacement in an X-axis direction at fixed intervals by a two-dimensional laser displacement meter having a measuring width that is at

least two or more times mean width of the roughness profile elements RSm of elements of a measurement target.

Advantageous Effects of Invention

5 [0021]

According to the present invention, it is possible to acquire surface roughness parameters from the surface of a measurement target quickly, successively, in large quantities, and directly, even if the measurement target is an
10 untransportable object, structure, or the like.

Brief Description of Drawings

[0022]

Fig. 1 is a schematic configuration diagram for
15 illustrating the configuration of a three-dimensional surface roughness evaluating device according to the present example.

Fig. 2 is a schematic configuration diagram for illustrating the configuration of a three-dimensional surface roughness data acquiring device.

20 Fig. 3 shows displacement data of X-Y plane coordinates when a painted plate 1 in a state where the surface of a metal plate is painted with paint (A state where the surface is coated with a dry coating film. The same applies to the following.) is measured as a measurement target.

Fig. 4 shows reference surface data of each coordinate generated by averaging in a Y-axis direction the displacement data of the X-Y plane coordinates in Fig. 3.

Fig. 5 shows reference surface data in which the
5 inclination of the reference surface data shown in Fig. 4 is corrected by a least squares method.

Fig. 6 shows three-dimensional surface roughness data obtained by subtracting the reference surface data shown in Fig. 4 from the displacement data shown in Fig. 3.

10 Fig. 7 graphically shows analytic results of surface roughness parameters obtained from the three-dimensional surface roughness data in Fig. 6.

Fig. 8 graphically shows analytic results of surface roughness parameters acquired by a laser displacement meter
15 mounted on an X-Y stage, regarding the painted plate 1 as a measurement target.

Fig. 9 is a comparative example of displacement data of X-Y plane coordinates when a range of 7.5 mm from the end of a Y-axis direction is measured, regarding the painted plate 1 as
20 a measurement target.

Fig. 10 shows reference surface data of each coordinate generated by averaging in the Y-axis direction the displacement data of the X-Y plane coordinates in Fig. 9.

Fig. 11 shows reference surface data in which the inclination of the reference surface data shown in Fig. 10 is corrected by the least squares method.

Fig. 12 shows three-dimensional surface roughness data
5 obtained by subtracting the reference surface data shown in Fig. 10 from the displacement data shown in Fig. 9.

Fig. 13 graphically shows analytic results of surface roughness parameters obtained from the three-dimensional surface roughness data in Fig. 12.

10 Fig. 14 is a graph showing the relation between the ratio of a measuring width to mean width of the roughness profile elements R_{Sm} of elements at a measuring width of 32 mm, and the percentage (%) of the maximum height of the roughness profile R_z at each measuring width to the maximum height of
15 the roughness profile R_z at a measuring width of 32 mm, regarding painted plates 2 to 6.

Fig. 15 is a histogram showing the distribution of surface roughness parameters when the three-dimensional surface roughness of a ship hull is measured as a measurement
20 target by use of the three-dimensional surface roughness evaluating device according to the present example.

Description of Embodiments

[0023]

Hereinafter, an embodiment (example) of the present invention will be described in more detail with reference to the drawings.

Fig. 1 is a schematic configuration diagram for illustrating the configuration of a three-dimensional surface roughness evaluating device according to the present example. Fig. 1(a) is a schematic configuration diagram seen from the side surface, and Fig. 1(b) is a schematic configuration diagram seen from the front surface.

[0024]

As shown in Fig. 1, a three-dimensional surface roughness evaluating device 10 according to the present example includes a two-dimensional laser displacement meter 12, a movement mechanism 14, a movement distance measuring device 16, a calculating device 18, and a transportable battery 20 serving to move the two-dimensional laser displacement meter 12, the movement distance measuring device 16, and the calculating device 18.

[0025]

It should be noted that, when it is not necessary to check a calculation result at a measurement site, the three-dimensional surface roughness evaluating device 10 can also be used as a three-dimensional surface roughness data acquiring device 30 if configured to store displacement data acquired by

the two-dimensional laser displacement meter 12 and movement distance data acquired by the movement distance measuring device 16 in a storage device 32 such as a hard disk drive or a flash memory, or transmit the data to a later-described external terminal by use of a communication means 34, as shown in Fig. 2.

[0026]

By separating the calculating device 18 in this way and thus using the external terminal as the calculating device 18, the device configuration at the measurement site can be simplified. It is also possible to calculate the acquired data by an external calculating device such as a personal computer, and display calculation results.

[0027]

It should be noted that, as the two-dimensional laser displacement meter 12, it is possible to use, without particular limitation, for example, LJ-V7080 (having a laser width of 32 mm at a reference distance) manufactured by Keyence Corporation.

Moreover, the two-dimensional laser displacement meter 12 is disposed so that the width direction of the two-dimensional laser displacement meter 12 is perpendicular to the movement direction (X-axis direction) of the movement mechanism 14, i.e., coincides with a Y-axis direction, to be

able to measure displacement data of coordinates in the Y-axis direction at a time at fixed intervals.

[0028]

Further, in the present example, the movement mechanism 14 includes two pairs of wheels (i.e., four wheels) movable only in a predetermined direction (X-axis direction). However, as long as the movement mechanism 14 is a mechanism movable only in a predetermined direction, the movement mechanism 14 is not particularly limited, and may be, for example, a crawler.

10 [0029]

Additionally, in the present example, a rotary encoder is used as the movement distance measuring device 16, and, by reading the number of revolutions of the wheel which is the movement mechanism 14, a movement distance is computed on the basis of the peripheral length and the number of revolutions of the wheel.

[0030]

It should be noted that the movement distance measuring device 16 is not limited to this, and can also be, for example, such a device as to read a movement distance with a scale sensor by a circular scale that operates together with the movement mechanism 14.

[0031]

Furthermore, the calculating device 18 is not particularly limited as long as the calculating device 18 is capable of computing surface roughness parameters or the like on the basis of the displacement data acquired by the two-dimensional laser displacement meter 12 and the movement distance data acquired by the movement distance measuring device 16, as described later. For example, the calculating device 18 can be configured to transmit the displacement data and the movement distance data to an external terminal such as a tablet computer, a smartphone, or a personal computer, then perform calculating processing, and display a calculation result on the external terminal.

[0032]

When the calculating device 18 is internally provided in the three-dimensional surface roughness evaluating device 10, a display means which displays calculation results of surface roughness parameters or the like may be provided, and it is also possible to provide a data output means so that the calculation results are transmitted to and displayed on, for example, the above-described external terminal.

[0033]

Moreover, as the transportable battery 20, it is possible to use, without particular limitation, an existing secondary

battery such as a lead storage battery, a nickel-hydrogen secondary battery, or a lithium-ion secondary battery.

[0034]

It should be noted that, although the three-dimensional
5 surface roughness evaluating device 10 is equipped with the
transportable battery 20 and is thus easy to carry in the
present example, the three-dimensional surface roughness
evaluating device 10 can also be configured so that electric
power for the two-dimensional laser displacement meter 12, the
10 calculating device 18, and others is supplied from, for example,
an external battery or a commercial power source.

[0035]

[Example 1]

A specific example of a surface roughness evaluation of
15 a measurement target 22 by the three-dimensional surface
roughness evaluating device 10 according to the present example
having the above configuration is shown below.

First, the three-dimensional surface roughness
evaluating device 10 is moved on the surface of the measurement
20 target 22 by the movement mechanism 14. Thereby, movement
distance data based on a movement distance obtained by the
movement distance measuring device 16 at fixed intervals, and
displacement data obtained by the two-dimensional laser

displacement meter 12 are recorded in the calculating device 18.

[0036]

Fig. 3 shows displacement data of X-Y plane coordinates when a painted plate 1 in a state where the surface of a metal plate is painted with paint is measured as the measurement target 22.

It should be noted that the displacement data shown in Fig. 3 are 121×121 (121 points in both the X-axis and Y-axis directions) pieces of data acquired with a pitch of 250 μm in a measurement area of 30 mm × 30 mm of the painted plate 1 by the three-dimensional surface roughness evaluating device 10 according to the present example. In the present example, such measurement was completed within one second.

[0037]

Then, the calculating device 18 generated reference surface data of each coordinate as shown in Fig. 4 by averaging displacement data of X-Y plane coordinates in the Y-axis direction.

[0038]

Reference surface data in which the inclination of the reference surface data shown in Fig. 4 is corrected by a least squares method are shown in Fig. 5. It should be noted that the vertical axis is enlarged to $\pm 30 \mu\text{m}$ in Fig. 5. It can be

seen by Fig. 5 that the reference surface data include an eccentricity of approximately $\pm 30\text{ }\mu\text{m}$ of the wheels which are the movement mechanism 14.

[0039]

5 Thus, the displacement data shown in Fig. 3 include the inclination of the measurement target 22, and eccentricity resulting from the rolling of the wheels which are the movement mechanism 14, in addition to surface roughness, and are not suited to a surface roughness evaluation. Accordingly, the
10 reference surface data shown in Fig. 4 are subtracted from the displacement data shown in Fig. 3 by the calculating device 18. Thereby, the inclination and the eccentricity resulting from the rolling of the wheels which are the movement mechanism 14 included in the displacement data are removed, and more
15 accurate three-dimensional surface roughness data can be acquired.

[0040]

Three-dimensional surface roughness data obtained in this way are shown in Fig. 6.

20 Fig. 7 graphically shows R_z (maximum height of the roughness profile), R_{Sm} (mean width of the roughness profile elements), R_{zjis} (ten-point mean roughness), R_a (arithmetical mean deviation of the roughness profile), R_q (root mean square deviation of the roughness profile), R_c (mean height of the

roughness profile elements), Rsk (skewness of the roughness profile), and Rku (kurtosis of the roughness profile) which are surface roughness parameters computed from the three-dimensional surface roughness data shown in Fig. 6, wherein
5 the minimum point of displacement is zero.

[0041]

Rz of the painted plate 1 was 78.9 μm , RSm was 3466 μm , Rzjis was 45.1 μm , Ra was 14.2 μm , Rq was 17.6 μm , Rc was 29.9 μm , Rsk was 0.08, and Rku was 2.7.

10 [0042]

[Comparative Example 1]

In order to verify the validity of the surface roughness parameters obtained by the three-dimensional surface roughness evaluating device 10 according to the present example, surface
15 roughness parameters in the same range as the measurement area of the painted plate 1 in Example 1 were measured by a laser displacement meter (point-like laser type displacement meter) mounted on an X-Y stage.

[0043]

20 When a measurement area of 30 mm $\times$ 30 mm of the measurement target 22 is measured with a pitch of 250 μm by the laser displacement meter mounted on the X-Y stage as in Example 1, it is necessary to repeat the process of measuring 121 points in the X-axis direction with a pitch of 250 μm , then

moving the laser displacement meter 250 μm in the Y-axis direction, and again measuring 121 points in the X-axis direction with a pitch of 250 μm . Thus, in the present comparative example, a time of approximately 5 minutes was
5 required for such measurement.

[0044]

Fig. 8 graphically shows computations of Rz (maximum height of the roughness profile), RSm (mean width of the roughness profile elements), Rzjis (ten-point mean roughness),
10 Ra (arithmetical mean deviation of the roughness profile), Rq (root mean square deviation of the roughness profile), Rc (mean height of the roughness profile elements), Rsk (skewness of the roughness profile), and Rku (kurtosis of the roughness profile) which are surface roughness parameters acquired by
15 the laser displacement meter mounted on the X-Y stage, regarding the painted plate 1 in Example 1.

[0045]

Rz of the painted plate 1 measured by the laser displacement meter was 78.1 μm , RSm was 3561 μm , Rzjis was 50.5
20 μm , Ra was 13.1 μm , Rq was 16.3 μm , Rc was 35.2 μm , Rsk was -0.11, and Rku was 2.8. Results equivalent to the surface roughness parameters obtained by use of the three-dimensional surface roughness evaluating device 10 according to Example 1 were obtained.

[0046]

[Comparative Example 2]

In order to simulate a case where a two-dimensional laser displacement meter having a laser width of 7.5 mm was used as
5 the two-dimensional laser displacement meter 12, surface roughness parameters in a range of 7.5 mm from the end of the Y-axis direction were measured, out of the measurement area of the painted plate 1 in Example 1. It should be noted that the configuration similar to that of the three-dimensional surface
10 roughness evaluating device 10 according to Example 1 was used except for the laser width of the two-dimensional laser displacement meter 12.

[0047]

Fig. 9 shows displacement data of X-Y plane coordinates,
15 in which 121×31 (121 points in the X-axis direction, and 31 points in the Y-axis direction) pieces of data were acquired with a pitch of 250 μm in a measurement area of 30 mm $\times$ 7.5 mm regarding the painted plate 1.

[0048]

20 As in Example 1, displacement data of X-Y plane coordinates were averaged in the Y-axis direction, and reference surface data of each coordinate shown in Fig. 10 were thus generated. Fig. 11 shows the inclination of the reference surface data corrected by the least squares method. As in Fig.

5, eccentricity of the wheels which are the movement mechanism 14 can be identified, but the width of the displacement is greater than that in Fig. 5.

[0049]

5 Fig. 12 shows three-dimensional surface roughness data in which the reference surface data shown in Fig. 10 are subtracted from the displacement data shown in Fig. 9, and the inclination and the eccentricity resulting from the rolling of the wheels which are the movement mechanism 14 included in the
10 displacement data are removed.

[0050]

 Fig. 13 graphically shows Rz (maximum height of the roughness profile), RSm (mean width of the roughness profile elements), Rzjis (ten-point mean roughness), Ra (arithmetical
15 mean deviation of the roughness profile), Rq (root mean square deviation of the roughness profile), Rc (mean height of the roughness profile elements), Rsk (skewness of the roughness profile), and Rku (kurtosis of the roughness profile) which are surface roughness parameters computed from the three-
20 dimensional surface roughness data shown in Fig. 12, wherein the minimum point of displacement is zero.

[0051]

 Rz of the painted plate 1 measured in Comparative Example 2 was 56.3 μm , RSm was 3900 μm , Rzjis was 34.9 μm , Ra was 10

μm , R_q was $12.4 \mu\text{m}$, R_c was $24.9 \mu\text{m}$, R_{sk} was 0.09 , and R_{ku} was 2.8 .

[0052]

In Comparative Example 2, the surface roughness parameters regarding roughness height including R_z , R_{zj} , R_a , R_q , and R_c are smaller than in Example 1 and Comparative Example 1. This is attributed to the fact that a surface roughness shape is included in the reference surface data averaged in the width direction (Y-axis direction) of two-dimensional laser.

[0053]

Another reason is considered to be that roughness height is undervalued if the measuring width (in Comparative Example 2, 7.5 mm which is a laser width) of the two-dimensional laser displacement meter 12 which is the length in the Y-axis direction to be averaged is excessively small as compared with R_{Sm} (mean width of the roughness profile elements) of the measurement target 22 ($3900 \mu\text{m} = 3.9 \text{ mm}$ in Comparative Example 2).

[0054]

In order to appropriately evaluate roughness height, the length (the measuring width of the two-dimensional laser displacement meter 12) in the Y-axis direction to be averaged is preferably two or more times R_{Sm} of the measurement target 22. The relation between the measuring width of the two-

dimensional laser displacement meter 12 and the mean width of the roughness profile elements R_{Sm} of the elements of the measurement target 22 is examined below.

[0055]

5 [Example 2]

Table 1 shows each surface roughness parameter obtained by measuring a painted plate 2 in a state where the surface of a metal plate is painted with paint as the measurement target 22, changing the measuring width of the two-dimensional laser displacement meter 12 to 0.5 mm, 1 mm, 2 mm, 4 mm, 16 mm, and 32 mm, and thus correcting by reference surface data averaged in the width direction (Y-axis direction) of two-dimensional laser at each measuring width.

[0056]

15 [Table 1]

Measuring width (mm)	Rz (μm)	R_{Sm} (μm)	Rzjis (μm)	Ra (μm)	Rq (μm)	Rc (μm)	Rsk	Rku
0.5	37.7	3140	26.4	6.2	7.7	17.9	0.0	2.9
1	64.5	3336	44.3	10.7	13.4	30.8	-0.1	3.0
2	91.3	3477	62.5	15.3	19.1	44.6	0.0	2.8
4	106.4	3545	73.0	18.0	22.5	52.0	0.1	2.9
8	113.1	3504	78.0	19.3	24.0	55.2	0.1	2.9
16	116.7	3554	80.5	19.9	24.8	57.7	0.2	2.9
32	111.8	3325	77.9	19.2	23.8	55.1	0.1	2.7

[0057]

As shown in Table 1, Rz, Rzjis, Ra, Rq, and Rc which are surface parameters regarding roughness height become smaller

as the measuring width becomes smaller. This is attributed to the fact that the amount of a surface roughness shape included in the reference surface data averaged in the width direction (Y-axis direction) of the two-dimensional laser displacement
 5 meter 12 increases as the measuring width becomes smaller.

[0058]

Moreover, it has become apparent that all of R_z , R_{zj} , R_a , R_q , and R_c , which are surface parameters regarding roughness height, tend to converge into true values as the
 10 measuring width becomes greater. This is attributed to the fact that a surface roughness shape is no longer included in the reference surface data averaged in the width direction (Y-axis direction) of two-dimensional laser if the measuring width becomes much greater than R_{Sm} .

15 [0059]

It should be noted that the maximum height of the roughness profile R_z at a measuring width of 32 mm is 111.8 μm , and the mean width of the roughness profile elements R_{Sm} of elements is 3325 μm .

20 Table 2 shows the ratio of each measuring width in Table 1 to R_{Sm} (3325 μm) at a measuring width of 32 mm, and the percentage of each surface roughness parameter at each measuring width in Table 1 to each surface roughness parameter at a measuring width of 32 mm.

[0060]

[Table 2]

Length (ratio) of measuring width to RSm at measuring width of 32 mm	Percentage (%) of each surface roughness parameter at each measuring width to each surface roughness parameter value at measuring width of 32 mm					
	Rz (%)	RSm (%)	Rzjis (%)	Ra (%)	Rq (%)	Rc (%)
0.2	33.7	94.4	33.9	32.2	32.3	32.5
0.3	57.7	100.3	56.8	55.7	56.1	55.9
0.6	81.7	104.6	80.2	79.7	80.1	80.9
1.2	95.2	106.6	93.7	94.0	94.3	94.4
2.4	101.2	105.4	100.1	100.5	100.8	100.2
4.8	104.4	106.9	103.3	103.7	103.9	104.7
9.6	100.0	100.0	100.0	100.0	100.0	100.0

[0061]

- 5 The percentage of Rz at each measuring width to Rz at a measuring width of 32 mm is 33.7% when the ratio of the measuring width to RSm at a measuring width of 32 mm is 0.2, 57.7% when 0.3, 81.7% when 0.6, 95.2% when 1.2, 101.2% when 2.4, and 104.4% when 4.8. It is apparent that the percentage
- 10 tends to converge into 100% as the ratio of the measuring width to RSm becomes greater. Particularly, the percentage converges into substantially 100% when the measuring width is approximately twice RSm.

[0062]

When an object having an unknown surface roughness shape is measured as the measurement target 22, it is also possible to vary the measuring width of the two-dimensional laser displacement meter 12 as above, and thus select, as a valid
5 measuring width, a range of measuring widths in which the variation of each surface roughness parameter is small.

[0063]

Table 3, Table 5, Table 7, and Table 9 respectively show
10 below roughness evaluation results obtained by measuring painted plates 3 to 6 in a state where the surfaces of metal plates are painted with paint as the measurement targets 22 in a similar manner, changing the measuring width of the two-dimensional laser displacement meter 12 to 0.5 mm, 1 mm, 2 mm,
15 4 mm, 16 mm, and 32 mm, and thus correcting by reference surface data averaged in the width direction (Y-axis direction) of two-dimensional laser at each measuring width.

[0064]

The maximum height of the roughness profile R_z with the
20 measuring width of the painted plate 3 at 32 mm was 60.4 μm , and the mean width of the roughness profile elements R_{Sm} of elements was 1820 μm . The maximum height of the roughness profile R_z with the measuring width of the painted plate 4 at 32 mm was 146.3 μm , and the mean width of the roughness profile

elements RSm of elements was 2200 μm . The maximum height of the roughness profile Rz with the measuring width of the painted plate 5 at 32 mm was 76.5 μm , and the mean width of the roughness profile elements RSm of elements was 4150 μm .

5 The maximum height of the roughness profile Rz with the measuring width of the painted plate 6 at 32 mm was 112.3 μm , and the mean width of the roughness profile elements RSm of elements was 5001 μm .

[0065]

10 Table 4 shows the ratio of each measuring width in Table 3 to RSm (3325 μm) at a measuring width of 32 mm, and the percentage of each surface roughness parameter at each measuring width in Table 3 to each surface roughness parameter at a measuring width of 32 mm. Similarly, Table 6 shows those in Table 5, Table 8 shows those in Table 7, and Table 10 shows those in Table 9.

[0066]

[Table 3]

Measuring width (mm)	Rz (μm)	RSm (μm)	Rzjis (μm)	Ra (μm)	Rq (μm)	Rc (μm)	Rsk	Rku
0.5	38.9	1871	27.0	5.1	6.7	15.0	0.0	4.0
1	50.5	1880	34.7	6.7	8.7	19.4	0.2	4.0
2	57.1	1902	38.6	7.4	9.7	21.5	0.2	4.2
4	60.7	1904	40.7	7.8	10.2	22.5	0.3	4.4
8	62.7	1915	41.7	8.0	10.5	23.3	0.4	4.5
16	63.7	1918	42.4	8.1	10.7	23.4	0.4	4.5
32	60.4	1820	40.2	7.8	10.2	22.2	0.4	4.2

[0067]

[Table 4]

Length (ratio) of measuring width to RSm at measuring width of 32 mm	Percentage (%) of each surface roughness parameter at each measuring width to each surface roughness parameter value at measuring width of 32 mm					
	Rz (%)	RSm (%)	Rzjis (%)	Ra (%)	Rq (%)	Rc (%)
0.3	64.5	102.8	67.2	66.2	65.6	67.6
0.5	83.6	103.3	86.4	86.2	85.1	87.3
1.1	94.6	104.5	96.0	95.3	94.7	96.8
2.2	100.5	104.6	101.1	100.5	100.3	101.3
4.4	103.9	105.2	103.7	103.5	103.4	104.7
8.8	105.5	105.4	105.4	105.0	105.0	105.3
17.6	100.0	100.0	100.0	100.0	100.0	100.0

[0068]

5 [Table 5]

Measuring width (mm)	Rz (μm)	RSm (μm)	Rzjis (μm)	Ra (μm)	Rq (μm)	Rc (μm)	Rsk	Rku
0.5	72.5	2352	52.1	11.0	13.9	32.5	0.0	3.2
1	109.6	2343	79.0	16.9	21.3	48.4	0.0	3.1
2	131.0	2335	94.9	20.4	25.7	58.8	0.1	3.1
4	144.8	2334	104.3	22.7	28.5	65.3	0.2	3.1
8	150.1	2372	109.6	24.0	30.1	30.1	0.3	3.1
16	154.4	2341	112.3	24.6	31.0	69.9	0.4	3.2
32	146.3	2200	107.2	23.4	29.5	66.5	0.4	3.0

[0069]

[Table 6]

Length (ratio) of measuring width to RSm at measuring width of 32 mm	Percentage (%) of each surface roughness parameter at each measuring width to each surface roughness parameter value at measuring width of 32 mm					
	Rz (%)	RSm (%)	Rzjis (%)	Ra (%)	Rq (%)	Rc (%)
0.2	49.6	106.9	48.6	47.2	47.3	48.9
0.5	74.9	106.5	73.7	72.2	72.3	72.8
0.9	89.5	106.2	88.5	87.2	87.2	88.5
1.8	99.0	106.1	97.3	96.9	96.7	98.2
3.6	102.6	107.8	102.2	102.4	102.0	104.1
7.3	105.6	106.4	104.8	105.2	105.0	105.1
14.5	100.0	100.0	100.0	100.0	100.0	100.0

[0070]

[Table 7]

Measuring width (mm)	Rz (μm)	RSm (μm)	Rzjis (μm)	Ra (μm)	Rq (μm)	Rc (μm)	Rsk	Rku
0.5	25.3	2676	17.5	3.9	5.0	10.8	0.0	3.1
1.0	41.2	3056	28.0	6.8	8.5	18.7	0.0	2.9
2.0	57.8	3563	38.3	9.7	12.2	27.0	-0.1	2.9
4.0	71.2	3955	46.0	12.2	15.3	34.4	0.0	2.8
8.0	77.7	4147	49.2	13.4	16.8	37.3	0.1	2.9
16.0	81.8	4267	51.7	14.3	17.8	39.8	0.2	2.8
32.0	76.5	4150	48.1	13.5	16.8	37.6	0.3	2.6

5 [0071]

[Table 8]

Length (ratio) of measuring width to RSm at measuring width of 32 mm	Percentage (%) of each surface roughness parameter at each measuring width to each surface roughness parameter value at measuring width of 32 mm					
	Rz (%)	RSm (%)	Rzjis (%)	Ra (%)	Rq (%)	Rc (%)
0.1	33.1	64.5	36.3	29.0	29.6	28.8
0.2	53.9	73.6	58.2	50.1	50.5	49.7
0.5	75.6	85.9	79.5	72.0	72.5	72.0
1.0	93.0	95.3	95.5	90.4	90.8	91.7
1.9	101.6	99.9	102.3	99.0	99.6	99.4
3.9	107.0	102.8	107.3	105.4	105.8	106.0
7.7	100.0	100.0	100.0	100.0	100.0	100.0

[0072]

[Table 9]

Measuring width (mm)	Rz (μm)	RSm (μm)	Rzjis (μm)	Ra (μm)	Rq (μm)	Rc (μm)	Rsk	Rku
0.5	21.6	3913	14.0	3.5	4.4	10.1	0.0	3.0
1.0	36.9	4140	23.6	6.3	7.8	18.3	0.0	2.9
2.0	64.3	4689	40.0	11.1	13.8	32.5	0.0	2.8
4.0	94.9	5257	55.9	16.4	20.4	48.3	0.1	3.0
8.0	104.7	5309	62.7	18.3	22.7	54.6	0.1	2.9
16.0	114.0	5365	69.7	19.9	24.8	59.8	0.2	2.9
32.0	112.3	5001	66.4	19.6	24.4	59.2	0.3	2.8

5 [0073]

[Table 10]

Length (ratio) of measuring width to RSm at measuring width of 32 mm	Percentage (%) of each surface roughness parameter at each measuring width to each surface roughness parameter value at measuring width of 32 mm					
	Rz (%)	RSm (%)	Rzjis (%)	Ra (%)	Rq (%)	Rc (%)
0.1	19.3	78.3	20.4	17.8	18.0	17.1
0.2	32.9	82.8	34.5	32.2	32.2	30.9
0.4	57.3	93.8	58.5	56.8	56.7	54.9
0.8	84.5	105.1	81.7	83.6	83.9	81.5
1.6	93.2	106.2	91.5	93.2	93.1	92.3
3.2	101.5	107.3	101.8	101.7	101.7	101.1
6.4	100.0	100.0	100.0	100.0	100.0	100.0

[0074]

The roughness evaluation results in all of the painted plates 3 to 6 apparently tend to converge into 100% as the ratio of the measuring width to RSm becomes greater, and particularly, apparently converge into substantially 100% when the measuring width is approximately twice RSm.

[0075]

Fig. 14 is a graph showing the relation between the ratio of a measuring width to mean width of the roughness profile elements RSm of elements at a measuring width of 32 mm, and the percentage (%) of the maximum height of the roughness profile Rz at each measuring width to the maximum

height of the roughness profile R_z at a measuring width of 32 mm, regarding painted plates 2 to 6

[0076]

As shown in Fig. 14, it has become apparent that, in all
5 of the painted plates 2 to 6, the percentage of R_z converges into 100% and does not vary to a great extent when the measuring width is approximately two or more times R_{Sm} .

[0077]

Thus, it has become apparent that, if the measuring width
10 of the two-dimensional laser displacement meter 12 is at least two or more times the mean width of the roughness profile elements R_{Sm} of the elements of the measurement target 22, the possibility that a surface roughness shape is included in the reference surface data averaged in the width direction (Y-axis
15 direction) of the two-dimensional laser decreases, and precision can be ensured.

[0078]

It should be noted that, when surface roughness parameters of the measurement target 22 having unknown
20 roughness are measured by use of the three-dimensional surface roughness evaluating device 10 according to the present invention, previously evaluating the mean width of the roughness profile elements R_{Sm} of the elements of the measurement target 22 by use of, for example, the method

according to the conventional technique as described above is also effective.

[0079]

Furthermore, when the mean width of the roughness profile
5 elements RSm of the elements of the measurement target 22 cannot be previously evaluated, it is possible to perform a high-precision surface roughness evaluation by changing the measuring width of the two-dimensional laser displacement meter 12, and then setting a range having no great variation in each
10 surface roughness parameter as a valid measurement width range, as stated above.

[0080]

[Example 3]

The three-dimensional surface roughness of a ship hull
15 was measured as the measurement target 22 by use of the three-dimensional surface roughness data acquiring device 30 and the calculating device 18 which is an external terminal. It should be noted that the configuration of the three-dimensional surface roughness data acquiring device 30 according to Example
20 3 is similar to that of the three-dimensional surface roughness evaluating device 10 according to Example 1 from which the calculating device 18 is omitted.

Fig. 15(a) is a three-dimensional histogram showing the distribution of Rz (maximum height of the roughness profile)

and RSm (mean width of the roughness profile elements) which are surface roughness parameters of a ship hull measured by use of the three-dimensional surface roughness data acquiring device 30. Fig. 15(b) is a histogram showing the distribution of the RSm component in Fig. 15(a). Fig. 15(c) is a histogram showing the distribution of the Rz component in Fig. 15(a).

[0081]

After the completion of the painting of the ship hull, the process of scanning 27 cm in the X-axis direction by use of the three-dimensional surface roughness data acquiring device 30, and acquiring 9 pieces of data of 30 mm × 30 mm was repeated. Measurements at 100 places were performed in the whole ship, and thus 900 pieces of data were acquired.

[0082]

It should be noted that the measurements at 100 places were completed in approximately 2 hours. Among 900 measurement points, there were 620 pieces of valid data, excluding measurement errors and the like. As a result of calculating processing on the basis of the acquired data in the calculating device 18 which was an external terminal on the basis of the acquired data, Rz (maximum height of the roughness profile) which was a surface roughness parameter was 50.7 μm , and RSm (mean width of the roughness profile elements) was 3187 μm .

[0083]

Moreover, the Rz distribution in the three-dimensional histogram shown in Fig. 15 was 20 μm to 140 μm , and the RSm distribution was 1750 μm to 7500 μm .

5 Reference Signs List

[0084]

- | | | |
|----|----|---|
| | 10 | Three-dimensional surface roughness evaluating device |
| | 12 | Two-dimensional laser displacement meter |
| 10 | 14 | Movement mechanism |
| | 16 | Movement distance measuring device |
| | 18 | Calculating device |
| | 20 | Transportable battery |
| | 22 | Measurement target |
| 15 | 30 | Three-dimensional surface roughness data acquiring device |
| | 32 | Storage device |
| | 34 | Communication means |

Claims

1. A three-dimensional surface roughness evaluating device comprising:

5 a two-dimensional laser displacement meter;

a movement mechanism which moves the two-dimensional laser displacement meter in an X-axis direction;

a movement distance measuring device which measures a movement distance of the two-dimensional laser displacement
10 meter in the X-axis direction; and

a calculating device which generates three-dimensional surface roughness data of a measurement target on the basis of displacement data acquired by the two-dimensional laser displacement meter and movement distance data acquired by the
15 movement distance measuring device, wherein

the two-dimensional laser displacement meter is disposed so that the width direction of the two-dimensional laser displacement meter coincides with a Y-axis direction, to be able to measure displacement data of coordinates in the Y-axis
20 direction at fixed intervals,

the measuring width of the two-dimensional laser displacement meter is at least two or more times mean width of the roughness profile elements R_{Sm} of elements of the measurement target, and

the calculating device is configured to

generate reference surface data of each coordinate by averaging in the Y-axis direction the displacement data acquired at fixed intervals in the X-axis direction by the two-dimensional laser displacement meter, and

generate three-dimensional surface roughness data of the measurement target by subtracting the reference surface data of each coordinate from the displacement data of each X-Y plane coordinate.

10

2. The three-dimensional surface roughness evaluating device according to claim 1, wherein the movement distance measuring device is a device which reads a movement distance with a scale sensor by a circular scale that operates together with the movement mechanism, or a device which reads the number of revolutions by a rotary encoder and computes a movement distance.

15

3. The three-dimensional surface roughness evaluating device according to claim 1 or 2, further comprising a transportable battery.

20

4. A three-dimensional surface roughness evaluating method of generating three-dimensional surface roughness data of a measurement target, the method comprising:

acquiring displacement data by measuring a displacement
5 in an X-axis direction at fixed intervals by a two-dimensional laser displacement meter having a measuring width that is at least two or more times mean width of the roughness profile elements RSm of elements of a measurement target;

averaging the displacement data in the Y-axis direction
10 and thus generating reference surface data of each coordinate; and

subtracting the reference surface data of each coordinate from the displacement data of each X-Y plane coordinate, and thus generating three-dimensional surface roughness data of
15 the measurement target.

5. A three-dimensional surface roughness data acquiring device comprising:

a two-dimensional laser displacement meter;

20 a movement mechanism which moves the two-dimensional laser displacement meter in an X-axis direction; and

a movement distance measuring device which measures a movement distance of the two-dimensional laser displacement meter in the X-axis direction, wherein

the two-dimensional laser displacement meter is disposed so that the width direction of the two-dimensional laser displacement meter coincides with a Y-axis direction, to be able to measure displacement data of coordinates in the Y-axis
5 direction at fixed intervals, and

the measuring width of the two-dimensional laser displacement meter is at least two or more times mean width of the roughness profile elements R_{Sm} of elements of a measurement target.

10

6. The three-dimensional surface roughness data acquiring device according to claim 5, wherein the movement distance measuring device is a device which reads a movement distance with a scale sensor by a circular scale that operates together
15 with the movement mechanism, or a device which reads the number of revolutions by a rotary encoder and computes a movement distance.

7. The three-dimensional surface roughness data acquiring
20 device according to claim 5 or 6, further comprising a transportable battery.

8. A three-dimensional surface roughness data acquiring method of acquiring three-dimensional surface roughness data of a measurement target, the method comprising:

acquiring displacement data by measuring a displacement
5 in an X-axis direction at fixed intervals by a two-dimensional laser displacement meter having a measuring width that is at least two or more times mean width of the roughness profile elements RSm of elements of a measurement target.