

Claims

1. A calibrated three-dimensional optical measuring apparatus (1), for the three-dimensional measurement of geometric parameters of a rope (2), comprising:
- 5 - a frame (3') which defines and is arranged around a rope receiving cavity (29);
- a plurality of image acquisition devices (C0, C1, C2, C3) adapted to acquire a multiplicity of digital images of at least one region of an outer surface (21) of the
- 10 rope (2), said image acquisition devices (C0, C1, C2, C3) being fixed to the frame (3') and being arranged around the rope (2) when the three-dimensional optical measuring apparatus (1) receives the rope (2) in the rope receiving cavity (29);
- 15 - an electronic digital image processing device, configured to process the multiplicity of digital images and to obtain a three-dimensional photogrammetric reconstruction of points of the digital images of the rope acquired by the image acquisition devices (C0, C1,
- 20 C2, C3);
- wherein, having defined a circumferential direction (C) running around a main extension axis of the rope (2) and lying on a plane (P) incident or perpendicular to the main extension axis of the rope (2), the image
- 25 acquisition devices (C0, C1, C2, C3) are arranged on the

frame (3') circumferentially spaced apart from one another along said circumferential direction (C), and wherein a lighting device (I0, I1, I2, I3) adapted to illuminate at least one region of the rope (2) is
5 arranged along the circumferential direction (C) between a pair of adjacent image acquisition devices (C0, C1; C1, C2; C2, C3; C3, C1).

2. A three-dimensional optical measuring apparatus (1) according to claim 1, wherein the electronic digital
10 image processing device comprises a storage unit, in which intrinsic and extrinsic calibration parameters of each image acquisition device (C0, C1, C2, C3) are stored.

3. A three-dimensional optical measuring apparatus (1) according to claim 1 or 2, wherein the frame (3')
15 comprises a casing (3) which defines and is arranged around the rope receiving cavity (29) and a support structure (10), joined to the casing (3), the image acquisition devices (C0, C1, C2, C3) being fixed on said
20 support structure (10).

4. A three-dimensional optical measuring apparatus (1) according to claim 3, wherein the support structure (10) comprises a joining region (11) releasably joined to the casing (3).

25 5. A three-dimensional optical measuring apparatus (1)

according to claim 3 or 4, wherein the support structure (10) is spaced apart from the casing (3) in the remaining portion of the support structure, which is different from the joining region (11).

5 6. A three-dimensional optical measuring apparatus (1) according to any one of claims 3 to 5, wherein, between the support structure (10) and the casing (3), a dampening element (5) is interposed, made of a material adapted to dampen the transmission of vibrations from the casing (3) to the support structure (10), for example a rubber or elastomeric material.

7. A three-dimensional optical measuring apparatus (1) according to claim 3, wherein the casing (3) and the support structure (10) are joined to form a single piece
15 or form part of a single piece.

8. A three-dimensional optical measuring apparatus (1) according to any one of claims 3 to 7, wherein the support structure (10) has an open annular shape, and the casing (3) has a box-like shape, said casing (3) being
20 arranged around the interior or the exterior of the support structure (10).

9. A three-dimensional optical measuring apparatus (1) according to claim 8, wherein the support structure (10) is arranged around the exterior of the casing (3) and
25 wherein the casing (3) comprises a casing side wall (31)

extending between a head end (32) and a tail end (33) along an axial direction (X') parallel to a main extension axis of the rope (2), said casing side wall (31) being adapted to be arranged spaced apart from the rope (2) when the three-dimensional optical measuring apparatus (1) relatively slides with respect to the rope (2), at least one viewing window (V0, V1, V2, V3) being obtained on said casing side wall (31) for each image acquisition device (C0, C1, C2, C3) so that the image acquisition device can detect a digital image of the rope (2) through said viewing window (V0, V1, V2, V3).

10. A three-dimensional optical measuring apparatus (1) according to any one of claims 8 to 9, wherein the casing (3) comprises a casing tail wall (331) and a casing head wall (321), which close the casing side wall (31) close to the tail end (33) and the head end (32), respectively, and wherein at least one passage opening (6, 6'), which is traversable by the rope (2), is obtained on each of said casing head wall (321) and casing tail wall (331), and wherein the tail wall (331) and the head wall (321) each comprise at least a first wall portion (321', 331') fixed and integral with the casing side wall (31) and a removable wall portion (321'', 331'') releasably fixed to the first wall portion (321', 331'), so that, in a rope insertion configuration, the removable

wall portion (321'', 331'') is not fixed to the first wall portion (321', 331') so as to leave a rope insertion opening (61) in the tail wall (331) and/or in the head wall (321), said rope insertion opening (61) communicating with the passage opening (6) to allow the insertion of the rope (2) in the passage opening (6, 6') by means of a relative movement between the casing (3) and the rope (2) perpendicular to the axial direction (X'),

and so that, in a rope installation configuration, the removable wall portion (321'', 331'') is fixed to the first wall portion (321', 331') so as to close the rope insertion opening (61).

11. A three-dimensional optical measuring apparatus (1) according to claim 10, wherein the removable wall portion (321'', 331'') at least partially defines the passage opening (6, 6').

12. A three-dimensional optical measuring apparatus (1) according to claim 10 or 11, wherein the first wall portion (321', 331') comprises at least one sliding guide in which the removable wall portion (331'', 321'') is slidably engaged to switch from an extracted configuration, in which the rope insertion opening (61) is exposed, to an inserted configuration, in which the removable wall portion closes the rope insertion opening

(61).

13. A three-dimensional optical measuring apparatus (1) according to any one of claims 9 to 12, wherein the casing side wall (31) comprises a fixed portion (31') defining an axial opening (28) extending mainly along the axial direction (X') between the head end (32) and the tail end (33),
and a movable portion (31''), for example a door, adapted to take a closed configuration, in which the movable portion closes the axial opening (28), and an open configuration, in which the movable portion (31'') is in a position which allows to access the axial opening (28), said axial opening (28) being traversable by the rope during a relative movement between the casing and the rope perpendicular to the axial direction (X').

14. A three-dimensional optical measuring apparatus (1) according to any one of claims 10 to 13, wherein, close to each rope passage opening (6, 6'), the three-dimensional optical measuring apparatus (1) comprises a shielding wall (65) projecting from the head wall (321) or from the tail wall (331) and extending internally towards the rope receiving cavity (29), so as to shield at least partially the entrance of light from outside the casing towards the rope receiving cavity (29).

15. A three-dimensional optical measuring apparatus (1)

according to any one of the preceding claims, wherein each lighting device (I0, I1, I2, I3) projects an illuminating beam (B0, B1, B2, B3) having an opening cone with a vertex angle (α_0 , α_1 , α_2 , α_3) such as to prevent
5 the light beam from intercepting a vision cone (w0, w1, w2, w3) of each image acquisition device (C0, C1, C2, C3) at least for a predefined distance (D), said predefined distance (D) being calculated as a distance starting from the image sensor plane (π) of an image acquisition device
10 and along a direction perpendicular to said image sensor plane (π) and towards the rope receiving cavity (29).

16. A three-dimensional optical measuring apparatus (1) according to any one of claims 9 to 15, wherein on an inner surface (310) of the casing side wall (31), facing
15 the rope receiving cavity (29), a material adapted to absorb light electromagnetic radiation and to reduce reflections is arranged, such as a black paint.

17. A three-dimensional optical measuring apparatus (1) according to any one of the preceding claims, wherein the
20 image acquisition devices (C0, C1, C2, C3) comprise at least a first pair of image acquisition devices (C0, C2) and a second pair of image acquisition devices (C1, C3), wherein the image acquisition devices of the first pair (C0, C2) are arranged in a diametrically opposite manner
25 and the image acquisition devices of the second pair (C1,

C3) are arranged in a diametrically opposite manner and are aligned along a perpendicular direction with respect to the alignment direction of the image acquisition devices of the first pair,

5 and wherein the lighting device (I0, I1, I2, I3) is interposed between the first and second pairs of image acquisition devices along the circumferential direction (C), and circumferentially spaced apart from the image acquisition devices.

10 18. A three-dimensional optical measuring apparatus (1) according to any one of the preceding claims, comprising an attachment device (4') adapted to constrain the three-dimensional optical measuring apparatus (1) to the rope in a relatively translatable manner with respect to the
15 rope (2);

19. A three-dimensional optical measurement method (1), for the three-dimensional measurement of geometric parameters of a rope (2), comprising the steps of:

a) providing a three-dimensional optical measuring
20 apparatus (1) comprising a plurality of image acquisition devices (C0, C1, C2, C3) fixed to a frame (3') and arranged spaced apart around the rope (2) along a circumferential direction (C) which runs around a main extension axis of the rope (2) and which lies on a plane
25 (P) incident or perpendicular to the main extension axis

- of the rope (2),
- wherein a lighting device (I0, I1, I2, I3) adapted to illuminate at least one region of the rope (2) is arranged along the circumferential direction (C) between
- 5 a pair of adjacent image acquisition devices (C0, C1; C1, C2; C2, C3; C3, C1);
- b) performing a relative movement between the rope (2) and the three-dimensional optical measuring apparatus (1);
- 10 c) during the relative movement of step b), lighting the rope by the lighting device (I0, I1, I2, I3) and acquiring a multiplicity of digital images of at least one region of an outer surface (21) of the rope (2);
- e) processing the multiplicity of digital images by means
- 15 of an electronic device and obtaining a three-dimensional photogrammetric reconstruction of points of the digital images of the rope (2) acquired by the image acquisition devices.