

Description

Device and method for the two-dimensional determination
5 of pendulum oscillations and/or rotations of loads on a crane

The invention relates to a device and a method
10 whereby pendulum oscillations of a load or load pick-up means which occur on a crane, as well as rotations (skew) of the same, can be detected and eliminated.

The aim, in crane installations, is to achieve increasingly automated unloading and loading cycles. A
15 conventional crane suitable for this purpose has a trolley which can move a load three-dimensionally via carrying ropes. In a rope-bound system of this type, the load will experience different accelerations and likewise execute pendulum oscillations of different
20 kinds. These pendulum oscillations must be compensated or eliminated before the load is deposited. In order to compensate the pendulum oscillations of the load automatically, the current deflection of the pendulum should be known at any point in time. For this purpose,
25 under the influence of external disturbance variables, such as, for example, pendulum oscillations due to strong wind, the pendulum angle of the load pick-up means must be measured regularly at short time intervals with a high degree of accuracy.

30 For measurement on crane systems, linear camera systems have been used hitherto, which are capable of determining one-dimensional pendulum oscillations in the direction of travel of the crane trolley. A system of this type is described in EP 0,596,330 B1. This
35 system serves for the detection of pendulum oscillations of loads on cranes by measurement, there being arranged, in the region of the load, a marking and, on the crane, a lighting means aligned with the

marking and also a detector aligned on the crane with the marking and having an image sensor oriented in the pendulum direction. The system, has furthermore, an evaluation means. However, this system cannot be used
5 in all crane types, since it is not possible to detect pendulum deflections perpendicular to the direction of travel of the crane trolley or rotational oscillations of the load. Furthermore, only a line-scan camera is used, which, as a rule, can supply only one-dimensional
10 image information on the state of oscillation.

The object on which the invention is based is to provide a reliable system and a method for the accurate two-dimensional optical measurement of pendulum oscillations and rotations of a load suspended
15 on a crane.

The solution for achieving this object emerges from the features of Claims 1 and 13.

The invention is based on the knowledge that the combined use of a solid-state camera (area-scan camera), of an infrared/lighting unit, of at least one
20 reflector which serves as a reference mark, and an evaluation unit for evaluating the reflector image received by the solid-state camera can be used a robust system for the accurate two-dimensional measurement of
25 the pendulum angle and rotation of a load which is suspended on a crane. In this case, the camera and lighting unit are expediently mounted on a crane trolley and aligned with a reflector which is attached to a load pick-up means. Reflectors of this system
30 preferably have at least one straight edge, thus making it easier to detect the image features and evaluate the image. If digital image processing is used, particular advantages are gained in terms of the processing speed. So that a reflector, which is measured as a reference
35 mark in its position in relation to a reference system, can be represented in the video image of the camera as a clearly identifiable bright area, the camera may be

preceded by one or more infrared filters. An LED (Light Emitting Diode) spotlight or a multiplicity of these is advantageously provided as an infrared lighting unit.

5 A two-dimensional tracking system is thus available, consisting of an intelligent matrix camera (CCD area-scan camera) and of infrared lighting on the crane trolley and also of a retro-reflector on the load pick-up means, by means of which system an accurate two-dimensional determination of the pendulum angle can
10 be carried out. The method is suitable for replacing the linear camera systems used hitherto, by means of which only one-dimensional pendulum oscillations in the direction of travel of the crane trolley can be determined.

15 Since the camera and lighting unit are arranged next to one another on a trolley, an advantageous refinement of the lighting unit consists of an infrared lighting ring formed around the camera. The reflectors of the load pick-up means may be composed of subunits,
20 so-called reflector segments. In order to classify the extent to which a reflector segment can reflect incident light back in the same direction, the divergence of a reflector segment is considered. The use of triple reflectors ensures that incident light is
25 reflected back in parallel in the direction of the light source. Extraneous light is therefore ruled out, since this is likewise reflected back to its original source and does not enter the scanning range of the camera. Reflectors of this type may be composed of
30 reflector segments of differing divergence, with a short distance between the camera and lighting unit, on the one hand, and the reflector, on the other hand, so that an evaluable image of the reflector is always recorded by the camera.

35 By attaching two or more spaced reflectors to a load pick-up means, it is possible in a simple way to determine a rotary position of a load pick-up means in

relation to a coordinate system of the camera or trolley.

It is advantageous, furthermore, to provide an electronic shutter in order to avoid motion blurs.

5 By means of image recordings succeeding one another in time, together with corresponding evaluations, the relative position of a load pick-up means can be constantly followed (tracking).

10 A range for a pendulum oscillation of $\pm 10^\circ$ and a distance range between the crane trolley and load pick-up of up to 50 m can be covered. If the rope length is measured currently and the value fed to an evaluation unit, the current size of the reflector image in the camera is known.

15 The entire system is expediently calibrated against the coordinates of the trolley of the crane via the camera.

The following advantages, in particular, are achieved by means of the invention:

- 20 - the laser power can be reduced, since the laser operates in the pulsed mode,
- the use of the image difference method makes it possible to eliminate the disturbing structures caused, for example, by sunlight,
25 - the design of the infrared spotlight as an annular arrangement consisting of a multiplicity of individual LED diodes makes it possible to have a compact form of construction in the region of the measuring camera.

30 Further exemplary embodiments are described below with reference to diagrammatic figures:

Figure 1 shows the sensor system for detecting the pendulum angle,

35 Figure 2 shows a top view of two reflectors 4 of square shape, the associated load pick-up means being rotated relative to the camera reference system,

Figure 3 shows a reflector composed of reflector segments having the same divergence,

Figure 4 shows a reflector composed of reflector segments of differing divergence,

5 Figure 5 shows a front view of a camera having a multiplicity of surrounding LED spotlights,

Figure 6 shows a flowchart of a reflector search by the image difference method.

10 The devices and the method for the two-dimensional determination of pendulum oscillations or rotations of loads can be used for the accurate two-dimensional and optical measurement of pendulum angles and for determining rotations of a load fastened to a load pick-up means, for a working range or for
15 carrying rope lengths of up to about 50 m. The two-dimensional tracking system consists of an intelligent matrix camera (CCD area-scan camera), which is mounted beneath a trolley 1 of a crane, and of a reference mark of predetermined shape or a reflector
20 (retro-reflector) fastened to the load pick-up means 5 which is connected to the trolley 1 via carrying ropes 7. The reflector is illuminated from the trolley by means of suitable infrared LED lighting. If suitable narrow-band infrared filters are used in front of the
25 camera, the reflector appears in the video image of the camera as a clearly identifiable bright area. The advantage of infrared LED lighting, as against conventional spotlights, is the high degree of robustness towards mechanical influences, the long life
30 and the low power consumption. The x, y position of a reflector in an expected range for a video image is calculated from the edge positions of the reflector by means of digital image-processing methods. By relating image to image in time, the reflector 4 can be followed
35 or tracked, with short evaluation times, and separation of disturbing objects can be carried out as a result of the known reflector shape (pattern-matching method).

Figure 1 shows diagrammatically a device for measuring pendulum angles in a pendulum angle range 8. A lighting unit consisting of LED spotlights 3, which are attached symmetrically relative to the camera 2 to the trolley 1 of a crane, are illustrated. A load pick-up means 5 (spreader of adaptable size) is suspended on the trolley 1 by carrying ropes 7, a load 6, in turn, being fastened to the load pick-up means 5. The direction of movement 11 of the trolley 1 is illustrated by a double arrow. Here too, the camera is again combined with a narrow-band infrared pass filter. The LED spotlights 3 may be arranged in a matrix-like manner or annularly in relation to the camera 2. The infrared LED diodes beam downwards and intensively illuminate the pendulum angle range 8 which amounts, for example, to $\pm 10^\circ$, calculated from the vertical. A reflector 4 on the load pick-up means sends the light back in the direction of the spotlights 3 and the camera 2. The camera 2, via an image evaluation computer integrated in the camera, determines the pendulum angle of the load 6 in two dimensions, that is to say relative to the plane coordinate axes x and y. The result is output, for example, via a field bus (profibus).

Figure 3 shows a reflector 4 composed of reflector segments 9 having identical divergence. An array or arrangement of reflecting triple reflectors (retro-reflectors) is shown. The triple reflectors send the incident light from a light source back in parallel in the direction of the light source. The arrangement therefore rules out extraneous light, since this is likewise sent back to the original source and does not enter the recording range of the camera. In order to achieve high luminance values, along with long working distances, it is advantageous to use reflectors of low divergence. The result of this, however, is that in the near range, that is to say up to a distance of about

4 m, the light is reflected excessively in the direction of the LED light sources and, because of the geometric distance between the camera and LED spotlight 3, only a little light enters the camera 2. In order to
5 prove the lighting contrast in the near range, there is provision for using a reflector 4 which consists of a matrix arrangement of retro-reflectors of low and high divergence in a geometric design which is advantageous for image evaluation. This ensures that an image
10 recording of the reflector, which represents a reference mark, is achieved with a high degree of luminance over the entire working range, see, in this respect, Figures 3 and 4. Geometric variants of the arrangement illustrated in Figure 3 are likewise
15 possible.

Figure 4 illustrates a reflector 4 which consists of reflector segments 9 and reflector segments 10, the reflector segments differing from one another in the amount of their divergence. Reflector segments 9
20 of low divergence cover the distant range, that is to say the greater distance between the trolley 1 and load pick-up means 5. The reflector segments 10 of high divergence cover the near range, so that, here too, light emitted by the LED spotlights 3 falls from the
25 reflector 4 into the camera 2 positioned directly next to the LED spotlights 3.

The detection of rotational oscillations or torsional oscillations of the load pick-up means 5 can be determined from the rotary position of a reflector
30 image after calibration and fixing of an image coordinate system or fixing of image coordinate axes on or in the camera. This is easily possible in the near range up to a distance of about 10 m. In order to achieve sufficient accuracy on a single reflector 4
35 during the processing of the associated image, a minimum quantity of pixels must be present. Since this number decreases in the case of greater distances

between the camera 2 and load pick-up means 5, the accuracy of evaluation by means of only a single reflector 4 also falls. It is advantageous, in the case of greater distances, to use an additional reflector 4.

5 The reflectors 4 serve as reference dimensions, that is to say their position or positioning relative to the load pick-up means 5 is known, so that the position of the load pick-up means 5 can be deduced directly from the position of the reflector 4 in the video image of

10 the camera 2. In the case of long distances, the viewing field of the camera 2 is sufficiently large always to cover both reflectors 4 in the image. Image evaluation determines in each case the centre points $(x_i, y_i; \text{ with } i = 1, 2)$. The current position (x_0, y_0) of

15 the load pick-up means 5 can then be calculated from the average value of the two reflectors.

$$x_0 = (x_1 + x_2) / 2$$

$$y_0 = (y_1 + y_2) / 2$$

The rotary angle ρ is obtained from the two

20 reflector centre points as

$$\rho = \arctan (y_2 - y_1) / (x_2 - x_1).$$

Image evaluation is carried out by means of an electronic shutter, in order to avoid motion blurs of the oscillating load. The camera image is then

25 evaluated automatically, by means of digital image-processing methods, by the evaluation unit (computing unit) contained in the camera. The most important features of image evaluation are

1. Taking into account the different size of

30 the reflectors in the image in the case of different rope lengths.

2. The substantial suppression of disturbing structures by checking the reflector geometry.

In order to carry out image evaluation, the

35 current distance between the camera 2 and the reflector 4 is transferred from the crane control to the evaluation unit, so that, during image evaluation, the

evaluation system knows the distant-dependent size of the reflector 4. In this case, search ranges can be set, which, in the image, restrict possible positions of the reflectors to be sought. The detection of disturbing structures is thus largely ruled out. The position of the reflector in the image is determined by edge-detection from the gradient of the digitized video data. In order further to suppress disturbing structures, the shape of the reflector is evaluated by means of statistical methods and by pattern-matching methods.

A reflector 4 may, for example, be of square design and have an edge length of 25 cm. In order to produce an operating range necessary when crane installations are in operation, the reflectors 4 can be adapted by being designed correspondingly with reflector segments 9, 10 of greater or lesser divergence. By means of appropriate calibration and the introduction of a camera reference system, a rotation of a load pick-up means 5 relative to the trolley 1 can be determined both in the near and the distant range.

Designing the LED spotlight as ring light minimizes the geometric distance between the camera and lighting. As a result, in conjunction with a retro-reflector, the lighting contrast in the camera image in the near range is improved. The LED spotlight may be operated in a pulsed manner synchronously with the camera, that is to say it is switched on only during the image recording time. The spotlight can thereby be operated at higher power, that is to say more brightness. The overall energy consumption falls, as a rule, as compared with a continuous-wave mode. At the same time, less heat is generated and the useful life of the LED spotlight is thereby increased.

The front view of the camera unit, as illustrated in Figure 5, shows the centrally positioned

camera objective 12 and the surrounding individual LEDs 13.

5 The flow chart according to Figure 6 relates to the image difference method. When switchable lighting or pulsed lighting is used, an image can in each case be recorded and stored, within a short time interval, with the lighting switched on and with it switched off. A difference image, in which disturbing structures caused by ambient light are suppressed, can be
10 calculated from these images by means of digital image processing.



Patent Claims

1. Device for the two-dimensional determination of pendulum oscillations and/or rotations of loads on a crane, consisting of:
 - a solid-state camera for two-dimensional image recording, which is mounted on a trolley (1) of a crane and is aligned with a load (6) suspended thereon,
 - 10 - an infrared lighting unit which is mounted directly next to the solid-state camera and beams in the direction of the load (6)
 - at least one reflector (4) fastened to a load pick-up means (5) and having a known orientation relative to the load pick-up means, in order to reflect infrared radiation emitted by the lighting unit back into the solid-state camera, and
 - 15 - an evaluation unit for calculating a pendulum angle and/or a rotary position of the load pick-up means (5) by means of the detected contour of the reflector (4).
2. Device according to Claim 1, wherein the contour of the reflector (4) has at least one straight edge.
- 25 3. Device according to one of the preceding claims, wherein the evaluation unit comprises digital image processing.
4. Device according to one of the preceding claims, wherein the camera is preceded by at least one infrared filter.
- 30 5. Device according to Claim 4, wherein the infrared filter is of narrow-band design.
6. Device according to one of the preceding claims, wherein the infrared lighting unit is pulsed and the pulse length is synchronized with the start and duration of the image recording time.
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7. Device according to one of the preceding claims, wherein the lighting unit consists of at least one infrared LED spotlight.
8. Device according to Claim 7, wherein a plurality of infrared LED spotlights are present, which form a matrix arrangement or a ring around the camera.
9. Device according to one of the preceding claims, wherein a plurality of reflector segments (9) forming a reflector (4) are triple reflectors of identical divergence.
10. Device according to Claim 9, wherein one reflector (4) consists of reflector segments (9) of differing divergence.
11. Device according to one of the preceding claims, wherein two or more spaced reflectors (4) are attached to the load pick-up means (5).
12. Device according to one of the preceding claims, wherein a solid-state camera with an electronic shutter for avoiding motion blurs is provided.
13. Method for the two-dimensional determination of pendulum oscillations and/or rotations of loads on a crane, using a device according to one of Claims 1-11, wherein
- a solid-state camera fastened to a trolley (1) of a crane records an image of a reflector (4) attached to a load pick-up means (5),
 - an infrared lighting unit positioned directly next to the solid-state camera illuminates the reflector (4),
 - the reflector (4) is represented in the video image of the camera as an evaluatable area.
14. Method according to Claim 13, wherein an image difference method is used in the detection of the reflector (4).
15. Method according to claim 13 or 14, wherein the camera image is evaluated by digital image processing based on the edge positions of the reflector image.



16. Method according to one of Claims 13-15, wherein the relative position of the reflector (4) is followed during successive evaluations.
17. Method according to one of Claims 13-16, wherein a separation of disturbing objects is carried out, during evaluation, by means of the known shape of the reflector (4).
18. Method according to one of Claims 13-17, wherein a pendulum range (8) of the load (6) of at least ± 10 degrees is covered.
19. Method according to one of Claims 13-18, wherein the size of the reflector (4) in the video image of the camera as a function of a current carrying rope length is taken into account.
20. Method according to one of Claims 13-19, wherein predetermined search ranges are used for the camera.
21. Method according to one of Claims 13-20, wherein a camera reference system is calibrated against the coordinates of the trolley (1).
22. Method according to one of Claims 13-21, wherein the determination of the rotation of the load pick-up means (5) is carried out by determining the relative rotary position of the edges of a reflector (4) in relation to the camera reference system.
23. Method according to one of Claims 13-22, wherein the rotation of the load pick-up means (5) is determined from the middle position of two spaced reflectors in relation to the camera reference system.