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(54) A MEASUREMENT APPARATUS FOR LONGITUDINAL DISPLACEMENTS OR SLIDING OF RAILS, FOR CONTROL FROM MOVING RAILWAY VEHICLES

(57) A measurement apparatus for longitudinal displacements or sliding of at least one rail (1), in particular a long welded rail (1). The measurement apparatus (100) comprises: a plurality of targets (111) constrained to the rail (1) and distributed along the rail (1); a respective plurality of light emitters (112) positioned on fixed supports in proximity of the rail (1), the plurality of light emitters (112) being configured to emit light references (113), the light references (113) fixed in space and respectively projected onto the plurality of targets (111); an image acquisition system (120) adapted to be mounted onboard a railway vehicle (2) and configured to frame each of the light references (113) projected onto a respective target (111); an image processing system (130) operatively connected to the image acquisition system (120) and configured to detect and measure a position of each light reference (113) on the respective target (111).

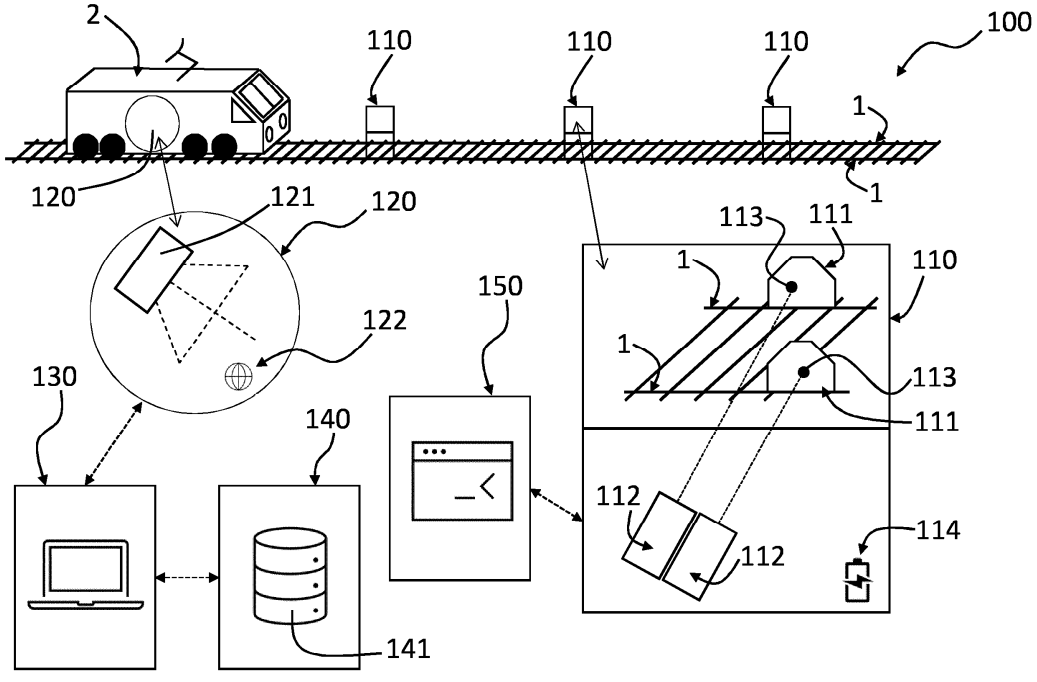

FIG. 1

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Description

Technical field

[0001] The present invention relates to a measurement apparatus for longitudinal displacements or sliding of at least one rail, in particular a long welded rail.

[0002] In general, the present invention is applied in the field of measuring longitudinal displacements of a rail, in particular made as Long Welded Rail (L.W.R.), by means of controls from moving railway vehicles.

Prior art

[0003] The variation of the Neutral Temperature (N.T.) of a rail - made as Long Welded Rail (L.W. R.) on tracks in operation - can be determined on the basis of the longitudinal displacements of the rail itself over time. The N.T. of a rail is defined as the temperature at which no internal stresses (elongation or shortening) are present in the rail itself.

[0004] The control operations involve conducting measurements of longitudinal displacements on the L.W.R. during operation, verifying that each of the two rails of the track undergoes - over time - only compatible longitudinal movements with respect to the position realised at the time of the adjustment of the internal tensions of the L.W.R. itself.

[0005] It is envisaged to calculate the alteration of the neutral temperature of the rails, normally referred to as the L.W.R. regulation, in the sections comprised between two measurement points.

[0006] The procedure for detecting and calculating the aforesaid alteration is as follows:

- detecting the longitudinal millimetre displacements of the rails at electrical tension poles or other fixed points located therebetween at a known distance (L);
- calculating the accumulation or thinning of the iron (ΔL) obtained by difference of the measured displacements;
- relating this value to the distance between the measurement points (L) and the linear expansion coefficient of the rails (e.g. 0.000012) to calculate the alteration of the neutral temperature ΔT of the individual rail, e.g. with the following relationship: $\Delta T = \Delta L / L * 0.000012$.

[0007] On the basis of the findings, in order to prevent possible traffic disruptions when extreme temperatures occur in the railway, the infrastructure manager takes any necessary measures to regularise the tension state or to prevent traffic disruptions (interruption of traffic, or slowing down of trains).

[0008] At present, the in-service inspection of the long welded rails of railway lines occurs with the direct intervention of railway infrastructure maintenance personnel who measure the longitudinal displacements of the rails with respect to immovable fixed points outside the track.

[0009] Patent application WO2008129420A3 in the name of Giorgio Pisani refers to a laser measurement method and system for inspecting, also in-service and in the construction phase, the longitudinal displacement of an L.W.R, which involves performing an initial series of reference measurements by means of a laser distance meter and reflection targets, and performing subsequent series of test measurements by means of a laser distance meter and reflection targets, in particular by rotating the laser distance meter on the two axes X and Y.

[0010] Patent application WO2022258650A1 in the name of Giorgio Pisani relates to a measurement system of longitudinal displacements or sliding of at least one welded rail comprising: centring means; an optical collimation device adapted to generate a collimation plane to perform a position reading of at least one fixed mark on said rail; a displacement device configured to provide a lateral displacement of the collimation plane; and a detection device configured to measure the lateral displacement.

[0011] Patent application CN108482421A relates to a displacement detection system for a long welded rail, comprising: basic field equipment, a main control operating system and a power supply system. The basic field equipment comprises an image acquisition system and a scale ruler, and the image acquisition system is used to emit a laser light mark on the scale ruler and used to collect the displacement image of the light mark on the scale ruler in real time and send the displacement image to the main control operating system. The main control operating system is used to receive the displacement image sent by the imaging system in real time and to measure and save the displacement based on the change in position of the light mark based on the comparison of the displacement image and a preset original image.

[0012] While allowing considerable savings in time and personnel, the solutions of the known art are not fully effective in measuring displacements or sliding also with the track in service.

[0013] For example, in order to assess the distance between the generated collimation plane and the marking on the rail, it is sometimes necessary to access the railway, either to carry out a more precise, short-distance survey or to carry out maintenance or installation of optical/electronic references fixed on the rail.

[0014] On the one hand, having to access the railway, it is appropriate to at least temporarily suspend train traffic, with remarkable disruptions on the line. On the other hand, a risk arises from having to access the railway, e.g. of injury or being hit, to which the operators are exposed.

[0015] Furthermore, known solutions require the organisation of demanding detection campaigns, walking the railway lines for almost their complete extension.

[0016] Therefore, the prior art solutions art can still be refined in certain aspects, solving technical problems

thereof.

Summary of the invention

[0017] An object of the present invention is to overcome drawbacks of the prior art.

[0018] A particular object of the present invention is to perform a measurement of longitudinal displacements or sliding, increasing the safety of operators.

[0019] A particular object of the present invention is to perform a measurement of longitudinal displacements or sliding, increasing the safety of railway traffic.

[0020] A particular object of the present invention is to present a measurement for longitudinal displacements or sliding of at least one rail, which is more efficient.

[0021] A further particular object of the present invention is to present a measurement apparatus for longitudinal displacements or sliding of at least one rail that allows, without interfering with the train traffic on the track in operation, to conduct all the control operations required by the regulations in force on the Long Welded Rail.

[0022] A further particular object of the present invention is to present a measurement apparatus for longitudinal displacements or sliding of at least one rail, which allows control operations to be performed in as automated a manner as possible.

[0023] These and other objects are achieved by means of a measurement apparatus for longitudinal displacements or sliding of at least one rail, in particular a Long Welded Rail, according to the features of the attached claims which form an integral part of the present description.

[0024] An idea underlying the present invention is to provide a measurement apparatus for performing detections onboard trains, with railway vehicles moving on a railway track that is also in service.

[0025] An aspect of the invention provides a measurement apparatus for longitudinal displacements or sliding of at least one rail, in particular a long welded rail.

[0026] The measurement apparatus comprises a plurality of targets constrained to and distributed along the at least one rail.

[0027] The measurement apparatus comprises a respective plurality of light emitters, located on fixed supports in the proximity of at least one rail. The light emitters are configured to emit light references. The light references are fixed in space. The light references are respectively projected onto the plurality of targets.

[0028] The measurement apparatus comprises an image acquisition system adapted to be mounted onboard a railway vehicle. The image acquisition system is configured to frame each of the light references projected onto the respective target of the plurality of targets.

[0029] The measurement apparatus comprises an image processing system operatively connected to the image acquisition system. The image processing system is configured to detect and measure one position of each of the light references on the respective target.

[0030] The present invention advantageously enables detection and measurement of longitudinal displacements of at least one rail, assessing the displacement of the light reference on the respective target constrained to the rail; each longitudinal sliding or displacement of the rail results in an apparent displacement of the light reference on the respective target, as the light emitters are located on fixed supports and generate fixed light references in space.

[0031] The present invention advantageously allows the image acquisition system to be used to frame the light reference and the image processing system to measure the position of the light reference on the target, whose longitudinal displacement is equal and opposite to the longitudinal displacement undergone by the rail.

[0032] Advantageously, the present invention reduces the risk of human error during measurement by using digital image acquisition and processing systems.

[0033] Advantageously, the present invention makes it possible to avoid operators having to access the track and to carry out detections from a railway vehicle, even in the presence of active railway traffic.

[0034] Advantageously, the present invention makes it possible to reproduce over time, for each light emitter, always the same light reference that intercepts, by means of a light spot or section, one or both of the two rails of the facing track.

[0035] Advantageously, the present invention makes it possible to measure a longitudinal displacement of the rails over time with respect to a stored or calibrated original position of the light reference on the target.

[0036] Advantageously, the present invention makes it possible, quickly, preferably automatically and without interfering with the traffic of trains in service on the track, to conduct all the control operations required by the regulations in force on the Long Welded Rail.

[0037] Advantageously, the present invention enables a calculation of the thermal tensional state of the Long Welded Rail, at the time of each survey, by means of the use of a calculation model that correlates the variation of Neutral Temperature with the longitudinal sliding of the rails.

[0038] Preferably, the measurement apparatus comprises a measured data processing system operatively connected to the image processing system and further operatively connected to a database. The measured data processing system is configured to receive the position of each of the light references on the respective target and to compare it with a previous stored position.

[0039] Advantageously, the measured data processing system makes it possible to automatically determine the longitudinal displacements or sliding of at least one rail, in particular of at least one long welded rail.

[0040] Advantageously, the data processing system makes it possible to automatically determine the deviation with respect to a Neutral Temperature (N.T.) of the at least one rail.

[0041] Advantageously, the present invention enables the automatic drafting of special verification tables for certifying the thermal tensional state of the Long Welded Rail at the time of detection.

[0042] Alternatively, the measured data processing system could be replaced by a user intervention, for manually processing the information provided by the image processing system, with respect to a data history.

[0043] Further features and advantages will become more apparent from the detailed description below of preferred, non-limiting embodiments of the present invention, and from the dependent claims outlining preferred, particularly advantageous embodiment of the invention.

Brief description of the drawings

[0044] The invention is illustrated with reference to the following figures, provided by way of non-limiting example, wherein:

- Figure 1 exemplifies a measurement apparatus for longitudinal displacements or sliding of at least one rail according to the present invention.
- Figure 2 illustrates a cross-sectional view of a track to which a measurement apparatus according to the present invention is applied.
- Figure 3 illustrates a longitudinal view corresponding to Figure 2.
- Figure 4 illustrates a cross-sectional view of a rail and a target constrained thereto.
- Figure 5 illustrates a longitudinal view corresponding to Figure 4.

[0045] In the different figures, similar elements will be identified by similar reference numbers.

Detailed description

[0046] Figure 1 exemplifies a measurement apparatus 100 for longitudinal displacements or sliding of at least one rail 1 according to the present invention.

[0047] As will be described, the measurement apparatus 100 allows the measurement of longitudinal displacements or sliding and the calculation of thermal alterations of the at least one rail 1 in an automatic manner, by means of suitably equipped railway vehicles 2 which during traffic interface with fixed devices 110 located along the railway line, i.e. the track comprising the at least one rail 1, in particular the at least one long welded rail 1.

[0048] As will be made clear below, the measurement apparatus 100 interfaces with devices preferably associated with each of the two rails 1 of the track; however, the operation of the measurement apparatus 100 is applicable separately to each rail, in cases where a monorail or a special three-rail track is presented instead of a conventional track. The invention will therefore refer to 'at least one rail', however, considering that the examples present a track with two respective rails. As will become clear, it is advantageous but not mandatory for the two targets 111 to be substantially aligned with each other in a position along the track.

[0049] The measurement apparatus 100 comprises a plurality of targets 111 constrained to the at least one rail 1 and distributed along the at least one rail 1.

[0050] The measurement apparatus 100 comprises a respective plurality of light emitters 112 located on fixed supports in the proximity of the at least one rail 1. Such fixed supports can be dedicated structures in the proximity of the tracks, or they can be immovable structures typically present in the proximity of a railway, such as electric traction poles, walls, pickets, etc.

[0051] The plurality of light emitters 112 are configured to emit light references 113. The light emitters 112 are normally switched off and are only activated when the equipped railway vehicle 2 arrives in the proximity.

[0052] In turn, the light references 113 emitted by the light emitters 112 are fixed in space and respectively projected onto the plurality of targets 111, in particular one light reference 113 for each target 111.

[0053] The light references 113 are preferably laser light, i.e. coherent light capable of defining a point or section of predefined dimensions and in a position that can be easily read, also from a certain distance. Furthermore, the light references 113 are preferably in visible light, e.g. a red or green point or section, but also in other colours or non-visible light, e.g. infrared light.

[0054] Preferably, the respective plurality of light emitters 112 comprises a respective plurality of power supply batteries 114. Alternatively, the respective plurality of light emitters 112 could be powered by a dedicated electrical mains, if present in the proximity of the fixed supports on which the light emitters 112 are located.

[0055] The measurement apparatus 100 comprises an image capture system 120, adapted to be mounted onboard the railway vehicle 2.

[0056] The image acquisition system 120 is configured to frame each of the light references 113 projected onto the respective target 111 of the plurality of targets.

[0057] In particular, the image acquisition system 120 comprises one or more cameras 121. There could be one camera 121 dedicated to framing each target 111, or a single camera 121 that frames both (or more) targets 111 positioned at each other, or three or more cameras 121 that cooperate with each other to frame the light references 113.

[0058] Preferably, the image acquisition system 120 further comprises a position module 122 configured to detect a measurement position of a respective target 111 at the at least one rail 1. The position module 122 could comprise a GPS system. In general, the position module 122 allows a geographical location to be associated with the image acquired by the image acquisition system 120, so that the target 111 and its position in the rail 1 can be precisely identified.

[0059] The railway vehicle 2, provided with the image acquisition system 120, therefore represents a 'diagnostic train', since at least part of the diagnostics of the at least one rail 1 is performed onboard the train.

[0060] The railway vehicle 2 could be a service vehicle without wagons, or a tractor pulling wagons (passenger or freight), or even a light railway vehicle such as a maintenance van with railway wheels. In a possible variant, the railway vehicle 2 could be an unmanned vehicle, i.e. remotely piloted or with autopilot, should standards and legislation permit, with further savings in personnel for the measurements.

[0061] Preferably onboard the railway vehicle 2, or at a remote location accessible by means of a data connection, the measurement apparatus 100 comprises an image processing system 130.

[0062] The image processing system 130 is operatively connected to the image acquisition system 120. In particular, the image processing system 130 is configured to receive one or more images, preferably digital images, acquired by the image acquisition system 120 and representing at least one light reference 113 on a respective at least one target 111.

[0063] The image processing system 130 is configured to detect and measure a position of each of the light references 113 on the respective target 111.

[0064] Preferably onboard the railway vehicle 2, or at a remote location accessible by means of a data connection, the measurement apparatus 100 comprises a measured data processing system 140.

[0065] The measured data processing system 140 is operatively connected to the image processing system 130 and further operatively connected to a database 141 for storing information.

[0066] The measured data processing system 140 is configured to receive the position of each of the light references 113 on the respective target 111, and to compare it with a previous stored position, in particular stored on the database 141.

[0067] Thereby, the measured data processing system 140 is able to determine the longitudinal displacements or sliding of at least one rail 1.

[0068] In other words, the measured data processing system 140 is configured to compare images of each of the light references 113 on the respective target 111 over time, in order to assess the variation corresponding to a longitudinal displacement or sliding of at least one rail 1.

[0069] Preferably onboard the railway vehicle 2, or at a remote location accessible by means of a data connection, the measurement apparatus 100 comprises a control system 150 operatively associated with the respective plurality of light emitters 112. The control system 150 is configured to activate or deactivate a light reference 113. In particular, such an activation or deactivation allows the light emitters 112 to be controlled when needed, i.e. only when the measurement of longitudinal displacement or sliding is to be performed.

[0070] In an embodiment, the control system 150 is configured to selectively activate or deactivate the emission of the light references 113, based on an external control. For example, the external control can be provided for a predetermined period to all the light emitters 112 on a section of railway line affected by the measurement. Alternatively, for example, the external control can be provided sequentially to one or more of the light emitters 112 along the section of railway line affected by the measurement, so as to activate the emission of the light reference 113 in a coordinated manner useful for the measurement from the railway vehicle 2.

[0071] In an embodiment, the control system 150 may involve receivers located along the line and operatively associated with the light emitters, whereby activation may also be done remotely by commands, e.g. via the Internet or with systems such as LoRa, Zigbee, Bluetooth, etc.

[0072] Figure 2 illustrates a cross-sectional view of a track including a pair of rails 1, to which a measurement apparatus 100 is applied, while Figure 3 illustrates a corresponding longitudinal view of the track.

[0073] In this embodiment, the control system 150 comprises a plurality of wireless signal receivers 151 in proximity of the plurality of light emitters 112. The control system 150 further comprises a wireless signal transmitter 152 in proximity of the image acquisition system 120, i.e. adapted to be mounted onboard the railway vehicle 2.

[0074] The plurality of wireless signal receivers 151 and the wireless signal emitter 152 are configured to activate one or more specific light references 113 when the image acquisition system 120 is approaching a respective specific light emitter 112.

[0075] Thereby, the awakening of the light emitters 112 occurs only when the railway vehicle 2 engaged in measurements passes by, and is thus expedient for the conservation of the battery 114. For example, the light emitters 112 could also be associated with solar panels for charging the battery 114.

[0076] In more detail, the light emitter 112 is normally in stand-by mode, and the wireless signal receiver 151 activates the emission of the light reference upon the approach of the railway vehicle 2 equipped with the wireless signal emitter 152. In turn, the wireless signal emitter 152 enables the temporary activation of the fixed light emitters 112 as the railway vehicle 2 passes.

[0077] In general, the light emitters 112 are configured to emit light references of a coherent shape, preferably being laser emitters, for example by emitting a vertical point or dash on a respective target 111 of the rail 1.

[0078] It is further appreciated in Figure 2 that the image acquisition system 120 is configured to frame each of the light references 113 projected onto the respective target 111 of the plurality of targets, in particular comprising a pair of cameras 121 each dedicated to framing a respective target 111.

[0079] In particular, preferably, one or more cameras 121 are applied to the railway vehicle 2, i.e. placed on board the railway vehicle 2, in a projecting position.

[0080] In general, one or more cameras 121 are positioned to continuously collimate, with the railway vehicle 2 moving, the side of the rails 1 and the targets 111 onto which the light references 113 are projected.

[0081] In an embodiment, a computer integrates the image processing system 130 and the measured data processing system 140 already described; by means of dedicated software, such a computer is configured to process the acquired images in real time, comparing them with those of previous measurements and thus immediately providing the calculation of the neutral temperature alteration of the individual rails 1.

[0082] Figure 4 illustrates a cross-sectional view of the rail 1 and a target 111 constrained thereto, while Figure 5 illustrates a longitudinal view corresponding to Figure 4 of the target 111.

[0083] As already described, the targets 111 are constrained to the at least one rail 1 and distributed along the at least one rail 1. **In** a non-limiting example, each target 111 is mounted by means of screw assembly of a special bracket surrounding the base of the rail 1; in general, different constraints are possible that allow the target to remain in position on the section of rail 1.

[0084] Preferably, the targets 111 have a predetermined shape adapted to be recognised by the image processing system 130.

[0085] In the example depicted, the shape of the targets 111 is substantially rectangular and comprises a triangular-shaped upper recess, defining a variable height of the target 111 with a minimum at the centreline, see Figure 5. This example is particularly advantageous because it allows the image processing system 130 to recognise the figure of the target, which, having predefined dimensions, allows an easy reconstruction of the position of the light reference 113 on the target 111, in order to assess the displacement thereof at a later time.

[0086] In other examples, the target could be of other more or less regular shapes and with different proportions, preferably optimised for image recognition techniques.

[0087] Preferably, the targets 111 comprise graphical identification codes, adapted to be recognised by the image processing system 130 for an identification of a specific target 111, and of the measurement thus acquired.

[0088] In the example shown, the target 111 comprises an alphanumeric graphical code, which is however recognisable by image processing system 130.

[0089] In other examples, the target could comprise graphical codes such as barcodes or area codes.

[0090] In general, the target 111 represents a non-confusable target, located integral with the rail 1, onto which light reference 113 is projected.

[0091] For target recognition, in addition to the aforementioned graphical codes, electronic systems such as encoders could also be used, or only GPS data could be used, e.g. provided by the position module 122 already described.

[0092] Preferably, the targets 111 are projecting with respect to the normal profile of the rails 111, but solidly anchored thereto in order to undergo the same longitudinal displacements. The particular shape, and the fact of being projecting, serves to facilitate the identification and position reading of the light reference 113 on the target 111.

[0093] The detection function is performed by the cameras 121 mounted on the railway vehicle 2. The difference in position of the spot of the light reference 113 on the target 111, detected during two different runs of the railway vehicle 2, allows the longitudinal displacement of the rails 1 to be measured as described above.

[0094] Advantageously, the position reading of the light references 113 on the targets 111 can also be done manually or with a portable camera and image processing system, by operators on site along the railway line. This is particularly useful for performing further verification measurements in the event of incidents.

Industrial applicability

[0095] In summary, the measurement apparatus according to the present invention enables measurements to be made at successive instants of time, by means of the acquisition and processing of images of fixed light references on special targets constrained to the rail, in order to detect and measure longitudinal displacements or sliding of the rails.

[0096] The measurement apparatus according to the present invention thus allows all measurement activities of longitudinal displacements or sliding during operation - required by the regulations in force on Long Welded Rail - to be carried out, with the simultaneous automatic drafting of the appropriate control and certification forms.

[0097] The present invention also makes it possible to transfer and process measurement data more efficiently and to automatically certify the thermal tensional state of the Long Welded Rail, at the time of detection, on special verification tables.

[0098] Furthermore, the present invention allows for a reduction in the time required to detect and immediately make data available on any alteration of the neutral temperature of the L.W.R.

[0099] The present invention further allows for a complete computerisation of the monitoring activity.

[0100] The present invention also makes it possible to reduce and eliminate errors due to the human factor.

[0101] The present invention also drastically reduces the cost of monitoring the conditions of the railway line.

[0102] In view of the description given herein, the person skilled in the art will be able to devise further modifications and variations, in order to satisfy contingent and specific needs.

[0103] For example, technical features described with reference to specific embodiments or variants may be transferred and combined in further embodiments and variants where there is no technical prejudice.

[0104] The embodiments described herein are therefore intended to be illustrative and non-limiting examples of the invention.

Claims

1. A measurement apparatus for longitudinal displacements or sliding of at least one rail (1), in particular of a long welded rail (1), said measurement apparatus (100) comprising:

   - a plurality of targets (111) constrained to said at least one rail (1) and distributed along said at least one rail (1);
   - a respective plurality of light emitters (112) located on fixed supports in proximity of said at least one rail (1), said plurality of light emitters (112) being configured to emit light references (113), said light references (113) being fixed in space and respectively projected on said plurality of targets (111);
   - an image acquisition system (120) adapted to be mounted onboard a railway vehicle (2) and configured to frame each of said light references (113) projected on a respective target (111) of said plurality of targets (111);
   - an image processing system (130) operatively connected to said image acquisition system (120) and configured to detect and measure a position of each of said light references (113) on said respective target (111).

2. The measurement apparatus according to claim 1, further comprising:

   - a measured data processing system (140) operatively connected to said image processing system (130) and further operatively connected to a database (141), said measured data processing system (140) being configured to receive said position of each of said light references (113) on said respective target (111) and to compare it with a previous position stored on said database (141), to determine said longitudinal displacements or sliding.

3. The measurement apparatus according to claim 1 o 2, further comprising a control system (150) operatively associated with said respective plurality of light emitters (112) and configured to activate or deactivate an emission of said light references (113).

4. The measurement apparatus according to claim 3, wherein said control system (150) further comprises a plurality of wireless signal receivers (151) in proximity of said plurality of light emitters (112), and wherein said control system (150) further comprises a wireless signal emitter (152) in proximity of said image acquisition system (120) and adapted to be mounted onboard said railway vehicle (2), wherein said plurality of wireless signal receivers (151) and said wireless signal emitter (152) are configured to activate at least a specific one of said light references (113) when said image acquisition system is approaching at least one respective specific light emitter (112).

5. The measurement apparatus according to claim 3, wherein said control system (150) is configured to activate or deactivate said emission of said light references (113) in a selective manner based on an external control.

6. The measurement apparatus according to any one of claims 1 to 5, wherein said plurality of targets (111) comprise targets having a predetermined shape and adapted to be recognized by said image processing system (130).

7. The measurement apparatus according to any one of claims 1 to 5, wherein said plurality of targets (111) comprise graphical identification codes, particularly alphanumeric codes, adapted to be recognized by said image processing system (130) for an identification of a specific target (111).

8. The measurement apparatus according to any one of claims 1 to 7, wherein said image acquisition system (120) further comprises a position module (121) configured to detect a measurement position of a respective target (111) at said at least one rail (1).

9. The measurement apparatus according to any one of claims 1 to 8, wherein said plurality of light emitters (112) are configured to emit coherent-shape light references, said light emitters (112) being preferably laser emitters.

10. The measurement apparatus according to any one of claims 1 to 9, wherein said respective plurality of light emitters (112) comprise a respective plurality of power supply batteries (114).

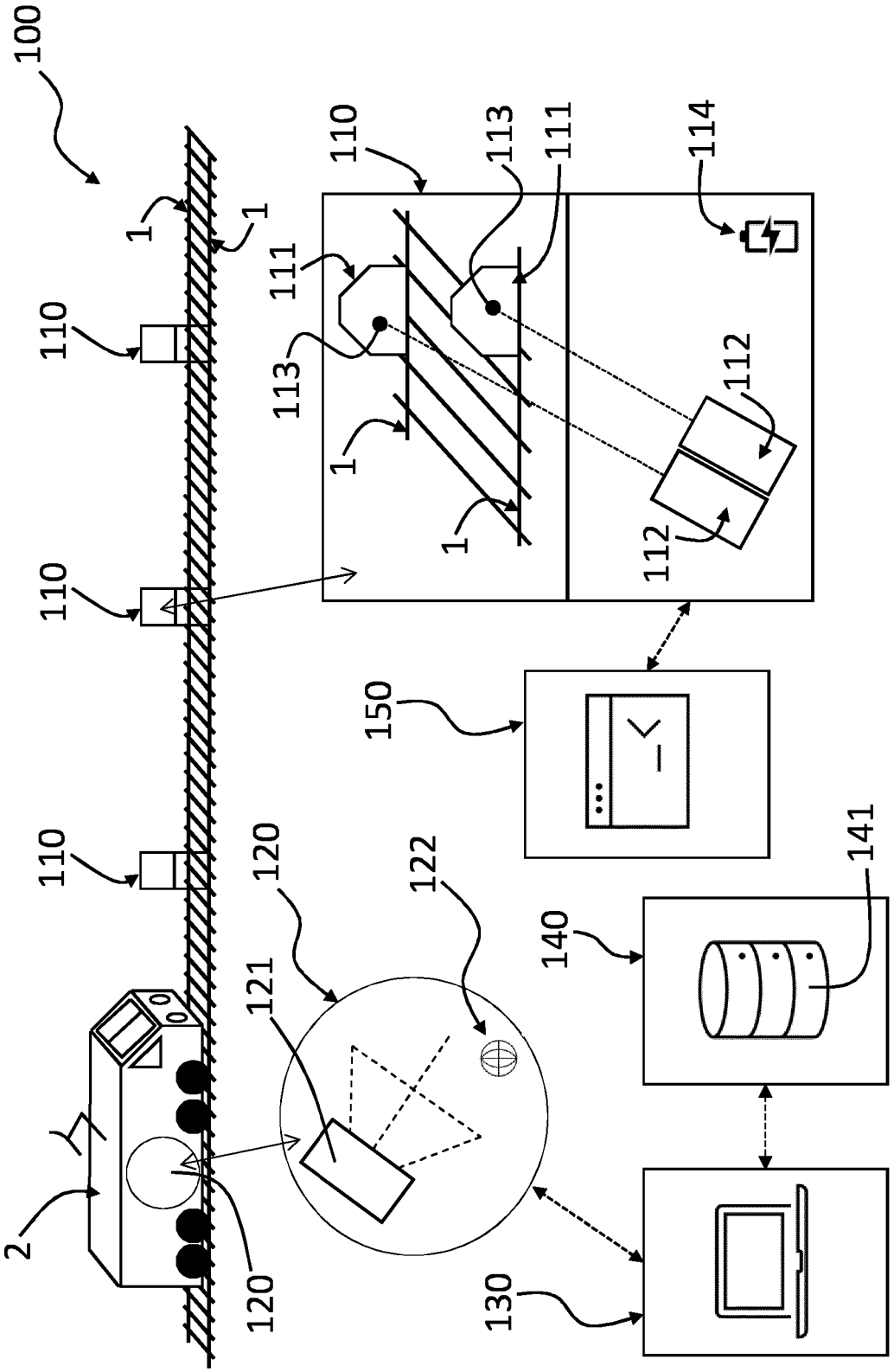
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FIG. 1

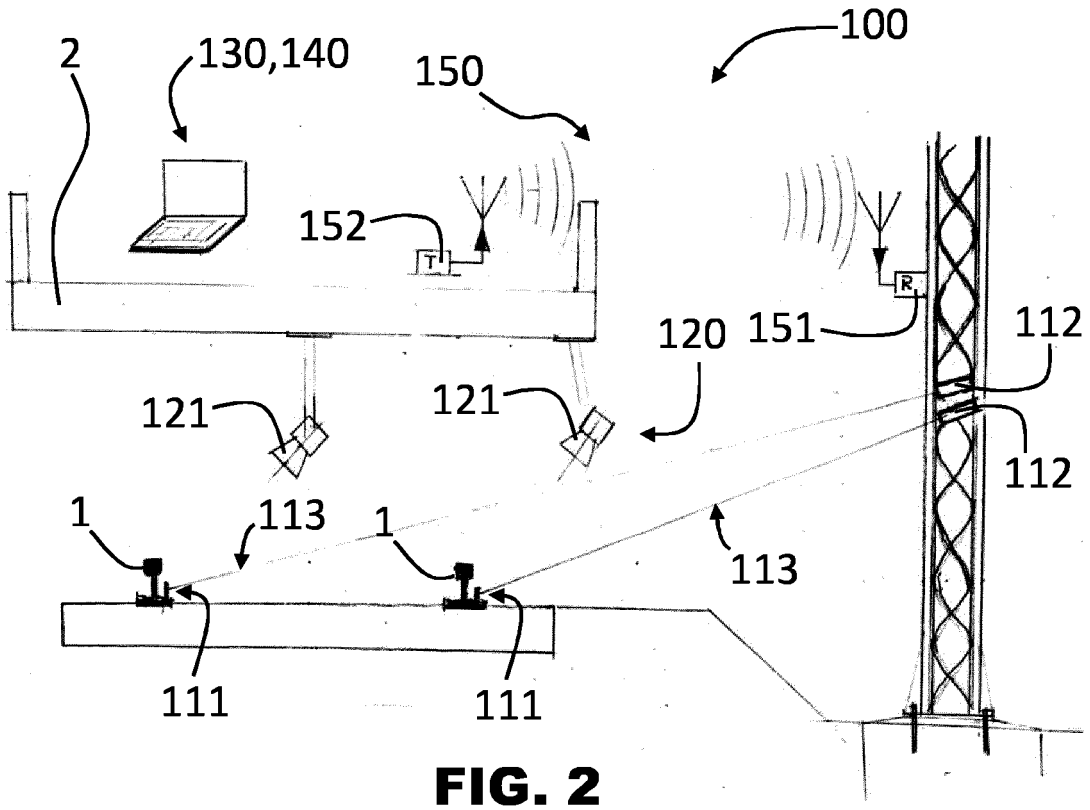
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FIG. 2

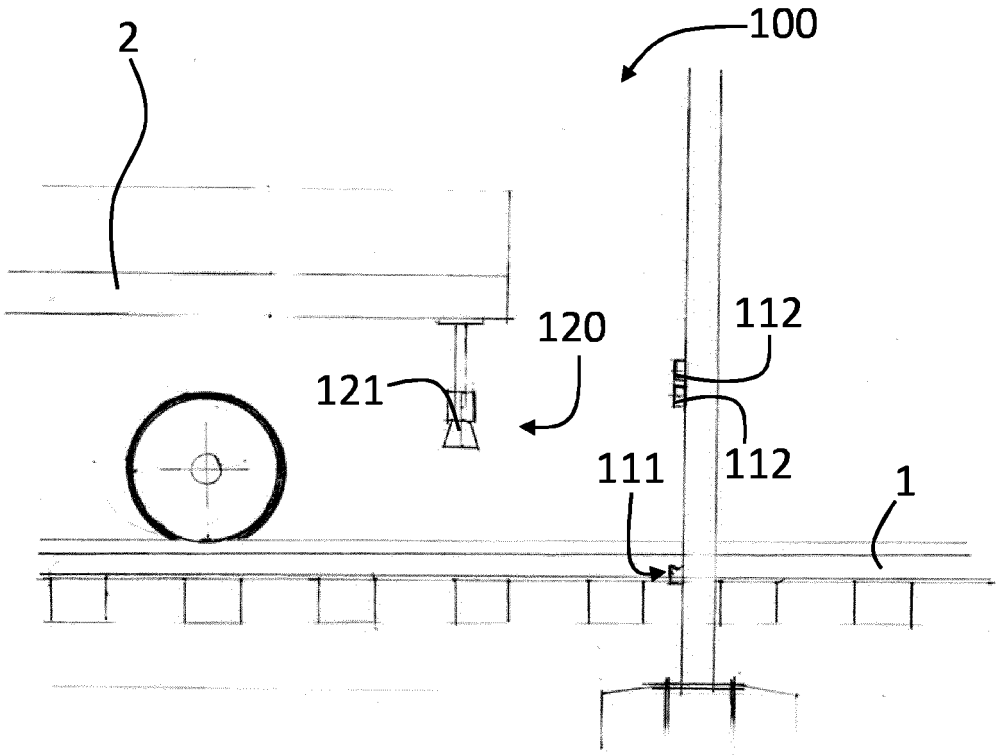
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FIG. 3

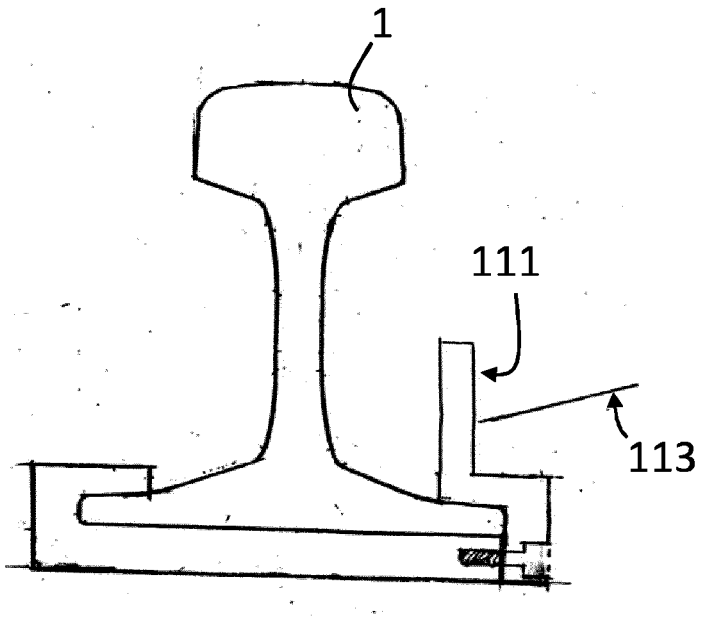

FIG. 4

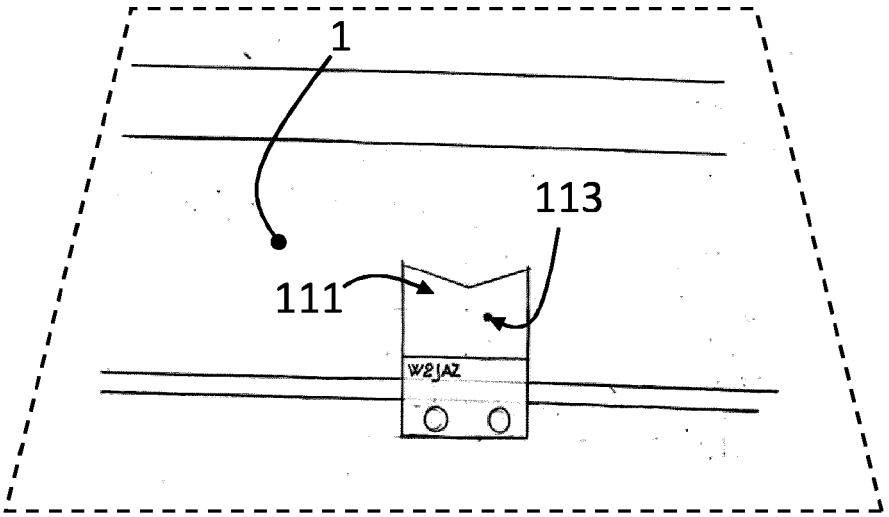

FIG. 5

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EUROPEAN SEARCH REPORT

Application Number
EP 25 18 8055

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Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
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TECHNICAL FIELDS SEARCHED (IPC)

B61L

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	18 November 2025	Janssen, Axel

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