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(54) METHOD AND SYSTEM FOR CONTROLLING A PAVING TRAIN

(57) Method for controlling a paving process, where the paving process is performed by a paving train (1) comprising at least a paving system (3) and a compaction system (4), comprising the steps of, continuously measuring an end result of the paving process by a sensor system (9) arranged at the end of the paving train, determining the end quality of the paving process by a control unit (8), comparing the determined end quality to an end quality specification, and adjusting at least one parameter of the paving process or paved material properties based on the determined end quality, if the determined end quality is outside of an end quality specification range.

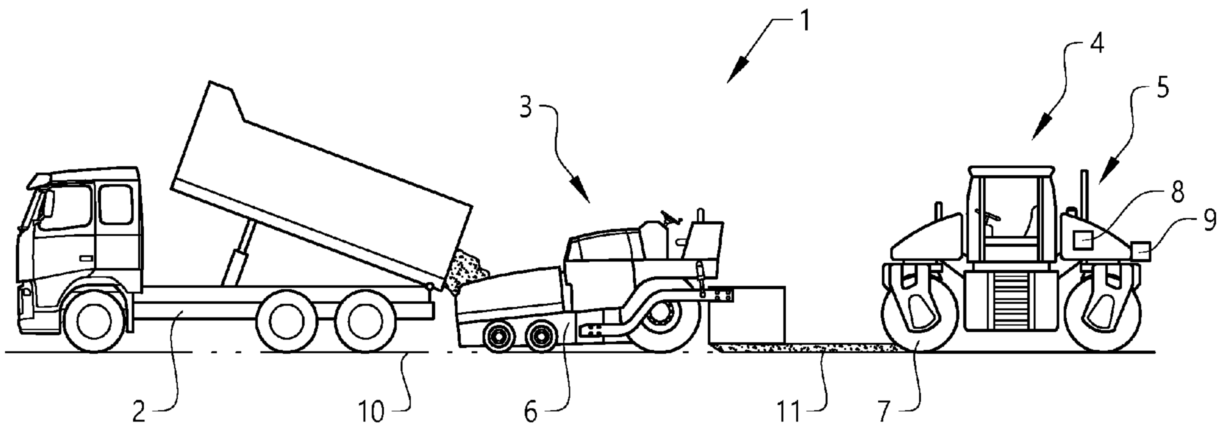

FIG. 1

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Description

TECHNICAL FIELD

[0001] The present invention relates to a method for controlling a paving train comprising at least a paving system and a compaction system. The end result of the paving process is measured by a sensor system arranged at the end of the paving train, and is used to determine if the end result is within an end quality specification range.

BACKGROUND ART

[0002] In road construction, the road surface is paved using a paving train comprising at least a paving machine and a compactor, where the paving machine spreads and compacts the road material, e.g. asphalt, in an even layer and where the compactor further compresses the asphalt to form the final road surface. The evaluation of the end result is normally carried out after the road surface is completed and the asphalt has cooled down. In one example, a measurement is carried out with a separate unit, e.g. a surface scanner after the job has been completed in order to evaluate e.g. cross-fall, smoothness, texture of the surface, density and compaction degree.

[0003] The quality of the result is largely based on experience and know-how of the operators of the paving machine and the compactor. A skilled operator may e.g. take account of environmental conditions such as temperature and humidity, and the temperature and quality of the material used. After the completed job, the surface may be evaluated, either by measuring or by visual inspection. Should some problems be detected, part of the surface may have to be repaved or repaired.

[0004] Compaction evaluation is done through destructive testing where core-samples are drilled in a random/pre-defined pattern. This is time consuming, bad for overall quality and shows the quality only in those specific spots with no way of knowing the result on the rest of the surface.

[0005] US 10480131 B1 discloses a method for controlling a paving process, where the paving process is performed by several participating units terminated by a compactor. The end result of the paving process is measured by a sensor system arranged on the compactor that measures e.g. material smoothness, stiffness and temperature. Based on the measured end result, the speed of paving machine units may be adjusted.

[0006] Such a paving method may function in some cases, but there is still room for an improved method for controlling a paving process.

DISCLOSURE OF INVENTION

[0007] An object of the invention is therefore to provide an improved method for controlling a paving process. A further object of the invention is to provide a control system for controlling a paving process in real time. A further object of the invention is to provide a paving train comprising such a control system. An object is also to provide a computer program and a computer program product adapted to perform the steps of the method.

[0008] The solution to the problem according to the invention is defined by the claims directed to a method, a control system and a paving train. The claims also contain advantageous further developments of the inventive method. Claims for a computer program and a computer program product are also enclosed.

[0009] In the inventive method for controlling a paving process, where the paving process is performed by a paving train comprising at least a paving system and a compaction system, the steps of, continuously measuring an end result of the paving process by a sensor system arranged at the end of the paving train, determining the end quality of the paving process by a control unit, comparing the determined end quality to an end quality specification, and adjusting at least one parameter of the paving process or paved material properties based on the determined end quality, if the determined end quality is outside of an end quality specification range are comprised.

[0010] With the inventive method, the end result of the paving process can be evaluated directly, and a parameter of the paving process can be adjusted based on the determined end result, if the end result is outside of an end quality specification range. In this way, the process can be evaluated and adjusted in real-time, such that the quality specification requirements can be met. If the system determines that the determined end quality is outside of the end quality specification range and that the adjustment of one or more parameters cannot achieve the end quality specification, the system may trigger an alarm. In this way, a paving process that will give a non-satisfactory end result can be stopped before any damage is done.

[0011] The determination of the end quality is performed by a control system that receives measurements from a sensor system comprising one or more sensors arranged at the rear of the paving train. The sensor system may be arranged on the compactor or on another vehicle at the end of the paving train, e.g. a separate truck, a measuring vehicle or a drone. The sensor system sends the measured values to a control system comprising a control unit arranged e.g. on the compactor. The used sensors may e.g. be a temperature sensor, a heat camera sensor, a laser sensor, an ultrasonic sensor, a ground radar sensor, etc. The control system may also receive environmental condition data, such as weather condition data, material temperature, information regarding the material production, and information regarding the material logistics.

[0012] In one example, the end result is represented by the surface geometry of the finished surface. The surface geometry may include at least one of surface texture, slope, surface smoothness, density, compaction degree, and longitudinal evenness of the surface.

[0013] The control system evaluates the measured values and determines an end quality result of the finished surface. The determined end quality is compared to an end quality specification, and if the determined end quality is outside of an end quality specification range, a parameter of the paving process is adjusted based on the determined end quality. Depending on the nature of the determined end quality, the parameter that is adjusted in the paving process may e.g. be the speed of the paving system and/or the compaction system. It is also possible to adjust the amount of compaction by the compactor.

[0014] It is also possible to use the determined end result to give feedback to the production plant of the surface material and/or the delivery logistics of the material, e.g. to adjust the temperature of the surface material depending on the delivery time or weather conditions. The surface material is in one example asphalt, but hydraulically bound material (RCC/CBM) could also be used.

[0015] With this method, it is possible to adapt the paving process directly when problems are detected, which makes it possible to correct faults and to eliminate large re-work of the surface. At the same time, the determined end result will provide traceability by providing continuous data over the entire surface, which may also be saved in a database for later reference. This will reduce the need for core-samples and instead give the possibility of testing in risk-areas where results may be more uncertain.

BRIEF DESCRIPTION OF DRAWINGS

[0016] The invention will be described in greater detail in the following, with reference to the attached drawings, in which

Fig. 1 shows a schematic paving train according to the invention,

Fig. 2 shows a further example of a paving train according to the invention, and

Fig. 3 shows a schematic flow chart of the inventive method.

MODES FOR CARRYING OUT THE INVENTION

[0017] The embodiments of the invention with further developments described in the following are to be regarded only as examples and are in no way to limit the scope of the protection provided by the patent claims.

[0018] Figs. 1 and 2 show a schematic paving train 1 comprising a paving system 3 and a compaction system 4. The paving system 3 comprises at least one paving machine 6 and the compaction system 4 comprises at least one compactor 7. The paving machine 6 and the compactor 7 may be combined in one unit that comprises both a paving function and a compaction function. Some paving machines comprises a screed that flattens the material, but a compactor is still used to achieve the final end result with regards to the compaction degree and surface smoothness. The paving train receives paving material such as asphalt from a transporting unit, e.g. a truck 2, driving in front of the paving machine 6. It is also possible to connect the truck to the paving machine, or to push the truck by the paving machine.

[0019] The paving machine distributes a layer of surface material 11 on the ground 10, and may also partially flatten the material. The thickness of the layer is predefined but could be changed slightly in dependency of the determined end result. The speed of the paving machine is e.g. set depending on the type of surface material, the temperature of the surface material and/or the thickness of the material layer. Preferably, the paving machine is driven by a constant and continuous speed, but it is possible to adapt the speed to the requirements. Should e.g. a truck delivering surface material be late, the paving machine may slow down temporarily.

[0020] The compaction system 4 comprises one or more units that have compaction capability, such as a compactor 7, a roller or a paver, which will compact the surface material to a predefined density and smoothness. The compactor normally drives in a predefined pattern that should give the surface its final shape. Depending on e.g. the surface temperature, the compacting pattern can be adjusted. By constantly measuring the end result, it is e.g. possible to control the position of the roller in relation to the border between cold and hot surface material. This will minimize errors in the stiffness measurement in the layer being compacted.

[0021] In the paving train, the different machines, such as a paving machine and a compactor, comprise various sensor that constantly measures different parameters of the paving process and adapts each machine to the measured values. The sensor values may also be sent to other machines for feedback puposes.

[0022] At the rear of the paving train 1, a sensor system 9 comprising one or more sensors is arranged in order to measure the end result of the paving process. The sensor system may be arranged on the compactor 7, or may be arranged on a specific measuring vehicle 12 or on a drone. The sensor system sends the measured end result values to a control system 5 comprising e.g. an electronic control unit (ECU) 8 running a computer program, which will determine an end quality value. The control system may also comprise a distributed computer system comprising several processors arranged either on-board or off-board the paving train. The control system compares the end quality value with a predefined end quality specification range. If the end quality value is outside of the end quality specification range, a parameter of the paving process or the surface material property is adjusted in order to bring the end quality back into the end quality specification range.

[0023] The sensors used in the sensor system may e.

g. include a thermal camera, IR sensors, surface scanners, radar, etc. and may be arranged on the compactor, on another vehicle, on a drone or may be handheld. The sensors may be connected to the control unit by cables or may be wireless. The control unit may be positioned on the compactor or may be arranged at a remote location. The control unit may communicate with the other parts of the paving train directly or through an external server.

[0024] The sensor system is adapted to measure e.g. cross-fall of the surface, compaction grade of the surface material, texture of the surface, smoothness of the surface, heat of the surface and a heat profile of the surface, and geo-positioning of the compactor.

[0025] By measuring the end result directly and giving feedback to the paving process in real-time, it may also be possible to adapt the process steps to changes in the used surface material. It is e.g. possible to adapt the compaction grade to condition changes in the process, such as the weather or the actual temperature of the asphalt. In this way, it may be possible to use asphalt that would normally be discarded, e.g. asphalt that would be considered to have a too low temperature, such that material must not be discarded.

[0026] In one example, as shown in Fig. 1, the paving machine 5 distributes the surface material 11, in this case asphalt, on the ground 10 in an even layer, where the thickness of the layer is set by the screed of the paving machine. A compactor 7 follows and compacts the asphalt to a final density. The compactor drives in a predefined pattern that is adapted to provide a desired compaction grade of the asphalt. The compactor is provided with a sensor system 9 that measures the end result of the compaction. The measured end result is processed in an ECU 8 that determines an end quality of the paving process and compares this end quality to an end quality specification. If the determined end quality is within an end quality specification range, the paving process can continue as it is. If the determined end quality is outside of the end quality specification range, one or more parameters of the paving process are adjusted in order to bring the determined end quality within the end quality specification range. Depending on the type of inconsistency or fault, different parameters may be adjusted.

[0027] In one example, the compaction grade is outside the desired range. In this case, it may suffice to drive the compactor over the surface one more time, or to use a vibrating compactor to bring the compaction grade within the desired range if the compaction grade is below the desired range. If the compaction grade is above the desired range, i.e. if the density is too high, it is possible to use less compaction or to increase the thickness of the asphalt layer. It may also be possible to change the paving speed.

[0028] It may also be that changes in the weather requires a higher temperature of the asphalt. In this case, the control unit can send a message to the asphalt plant to increase the temperature of the delivered asphalt.

[0029] In another example, shown in Fig. 2, the end result is measured by an additional vehicle, e.g. a measuring vehicle 12 or a drone. The measuring vehicle drives after the compactor and measures the end result of the surface. One advantage with using a separate measuring vehicle is that it is possible to attach more and different sensors to a separate vehicle, and that the sensors are not subjected to vibrations in the same way as when mounted on e.g. a compactor. Even if the paving train comprises several compactors, only one vehicle provided with sensors is required.

[0030] The measured end result is sent to a control unit arranged e.g. in the measuring vehicle, where the end quality is determined. The control unit may also be arranged at a remote location. The control unit sends adjustment messages if a parameter of the paving process should be adjusted.

[0031] Fig. 3 shows a schematic flow chart of the method for controlling a paving process.

[0032] In step 100, the end result of the paving process is measured by a sensor system arranged at the end of the paving train. The end result can be measured by one or more sensors, and the sensors may measure different values relevant to the end result.

[0033] In step 110, the end quality of the paving process is determined by a control unit. The control unit may be arranged at the same vehicle as the sensor, e.g. a compactor, or may be arranged at a remote location.

[0034] In step 120, the determined end quality is compared to an end quality specification. The end quality may be defined by one or more measurement values.

[0035] In step 130, at least one parameter of the paving process or paved material properties is adjusted based on the determined end quality, if the determined end quality is outside of an end quality specification range. In this way, the end result can be adjusted directly in real-time, which increases the quality and minimizes the need for rework of the finished surface.

[0036] The invention is not to be regarded as being limited to the embodiments described above, a number of additional variants and modifications being possible within the scope of the subsequent patent claims.

REFERENCE SIGNS

[0037]

1: Paving train
2: Truck
3: Paving system
4: Compaction system
5: Control system
6: Paving machine
7: Compactor
8: Control unit
9: Sensor system
10: Ground
11: Surface material

12: Measuring vehicle

Claims

1. A computer-implemented method for controlling a paving process, where the paving process is performed by a paving train comprising at least a paving system and a compaction system, the method comprising the steps of:

- continuously measuring an end result of the paving process by a sensor system arranged at the end of the paving train,
- determining the end quality of the paving process by a control system comprising a control unit,
- comparing the determined end quality to an end quality specification, and
- adjusting at least one parameter of the paving process or paved material properties based on the determined end quality, if the determined end quality is outside of an end quality specification range.

2. The method according to claim 1, further comprising the step of. triggering an alarm when the determined end quality is outside of the end quality specification range and the when the adjustment of parameters cannot achieve the end quality specification.

3. The method according to claim 1 or 2, wherein the end quality comprises a measured surface geometry.

4. The method according to claim 3, wherein the surface geometry includes at least one of surface texture, slope, surface smoothness, density, compaction degree, and longitudinal evenness of the surface.

5. The method according to any of claims 1 to 4, wherein the control system further receives condition data, such as weather condition data, material temperature, material production, delivery logistics.

6. The method according to any of claims 1 to 5, wherein an additional unit on, above or near the finished surface comprises an additional sensor that send data to the evaluating control unit.

7. The method according to any of claims 1 to 6, wherein the adjustment of at least one parameter of the paving system is performed in real-time.

8. The method according to any of claims 1 to 7, wherein the compactor comprises a temperature scanner that is used to position the compactor on the paved surface.

9. The method according to any of claims 1 to 8, comprising the additional steps of:

- measuring the heat of the material by the paving system and/or the compaction system,
- sending a message to the material production plant in dependency of the measured material temperature.

10. The method according to any of claims 1 to 9, wherein the sensors includes at least one of: a thermal camera, an IR sensor, a surface scanners, a radar, a moisture measuring sensor.

11. The method according to any of claims 1 to 10, wherein the control unit is arranged in the compaction system.

12. A computer program comprising program code means for performing all the steps of claims 1 - 11 when said program is run on a computer.

13. A computer program product comprising program code means stored on a computer readable medium for performing all the steps of claims 1 - 11 when said program product is run on a computer.

14. A control system (5) for controlling a paving process in a paving train (1) in real time, the control system (5) being configured to perform the steps of the method according to any one of claims 1 - 11.

15. A paving train (1), comprising a paving system (3), a compaction system (4) and a control system (5) according to claim 14.

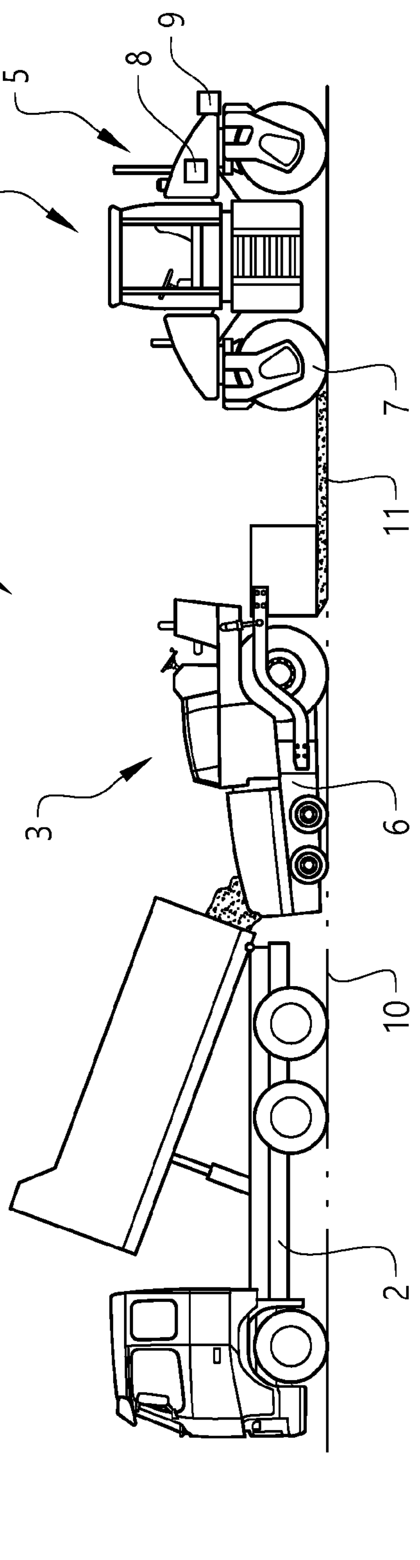

FIG. 1

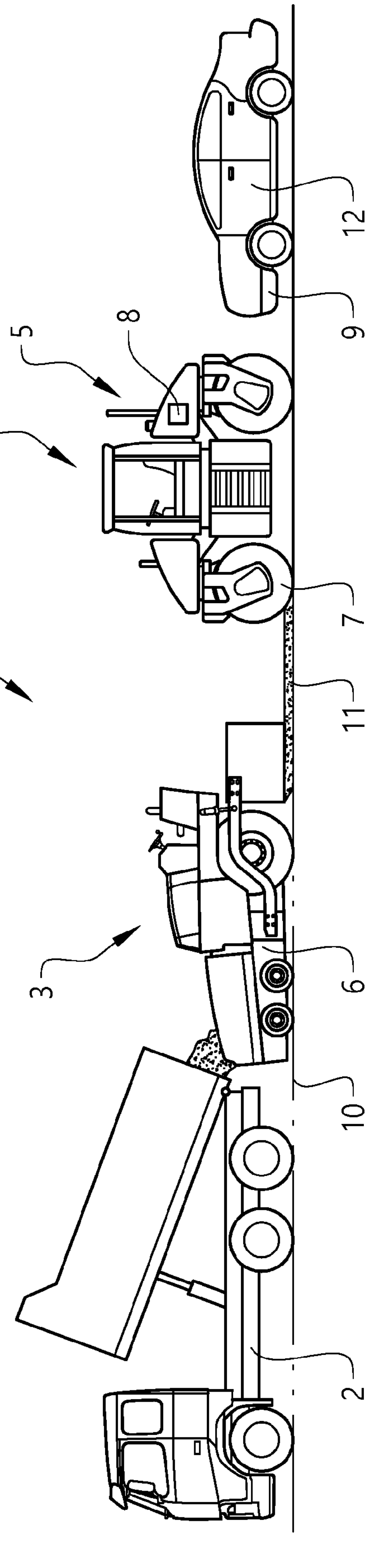

FIG. 2

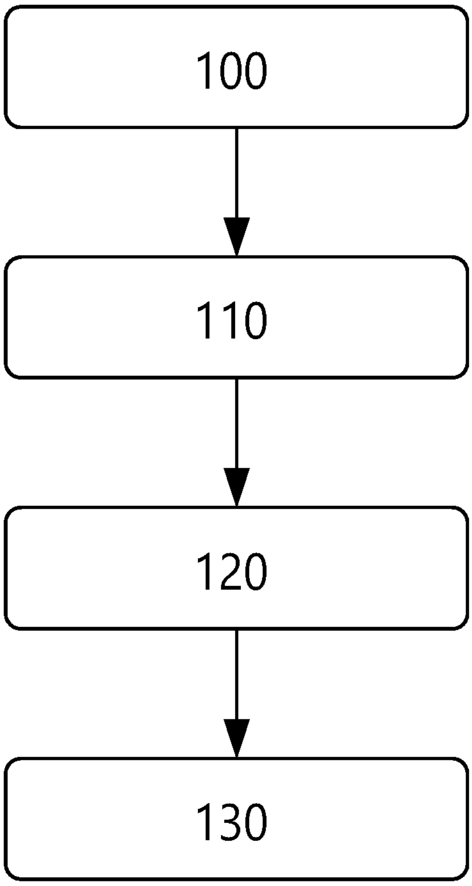

FIG. 3

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EUROPEAN SEARCH REPORT

Application Number
EP 22 20 0584

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	EP 3 680 833 A1 (TF TECH A/S [DK]) 15 July 2020 (2020-07-15) * figures 1-5 * * paragraphs [0001], [0002], [0009], [0011] - [0023], [0026] - [0044], [0050] - [0057] * * the whole document * -----	1-15	INV. E01C19/48 E01C19/28 E01C23/01 G05D1/02 G05D1/00
X,D	US 10 480 131 B1 (MCALPINE JACOB J [US] ET AL) 19 November 2019 (2019-11-19) * figure 1 * * column 3, line 10 - column 4, line 15 * * column 8, lines 44-47 * * column 9, line 25 - column 14, line 48 * * column 10, lines 27-42 * * the whole document * -----	1-15	

TECHNICAL FIELDS SEARCHED (IPC)

E01C
G05D

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
Munich	21 March 2023	Klein, A

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO.

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21-03-2023

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For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

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