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(54) **METHOD FOR DETERMINING REPLACEMENTS OF WEAR ELEMENTS, CORRESPONDING SYSTEM AND MACHINE**

(57) The invention relates to a method for determining replacements of wear elements of an earth-moving machine, corresponding system and machine. The method comprises monitoring said wear assembly (1) to:
- determine when the assembly is in a state suitable for replacement (200); and
- detect whether alert events (100) candidates to events of loss of the wear elements (2) take place;
for each alert event (100), performing the following steps:
- determining whether said wear assembly (1) has been in said state suitable for replacement (200) throughout an entire predetermined time window until said alert event (100) has taken place; and
- if this is the case, determining that said alert event (100) is an event of replacement of the wear element (2) corresponding to said alert event (100), thereby determining that a replacement of said wear element (2) has taken place.

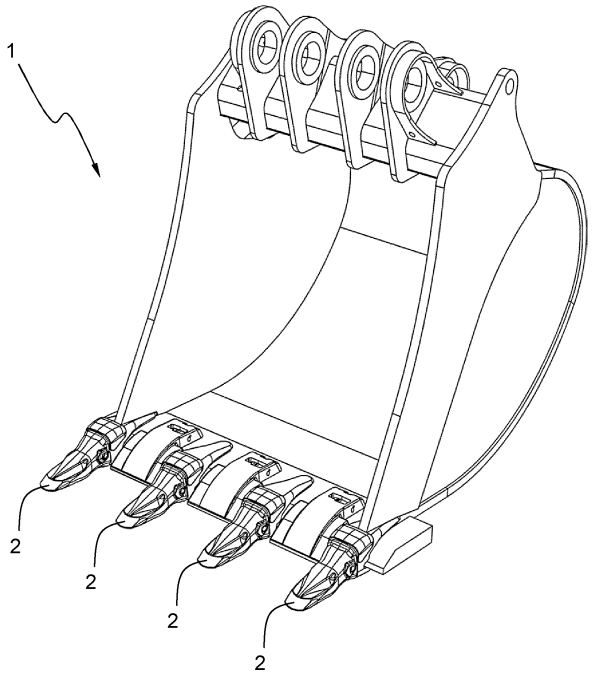

FIG. 1

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Description

Field of the Invention

[0001] The invention is comprised in the field of earth-moving machines, particularly for excavators, loaders, dredging machines, or the like.

[0002] More specifically, the invention relates to a method for determining replacements of the wear elements of a wear assembly of an earth-moving machine.

[0003] The invention also relates to a system for determining replacements of said wear elements, as well as the corresponding earth-moving machine.

State of the Art

[0004] In the field of earth-moving machines, the state of the different wear elements used must be monitored, in particular, to enable determining when said any of said elements needs to be changed. These wear elements are commonly known as GET (ground engaging tool), with a common example being the teeth of an excavator, but also adaptors, front guards, side guards, wear caps, among others.

[0005] Additionally, a characterization of the soils on which work is being carried out can be useful, such that the wear level involved for the different wear elements due to abrasion can be determined. For example, said characterization may allow anticipating the costs derived from the consumption of said elements, as well as supply needs in order to avoid having to stop working due to a lack of spare parts. The characteristics of each terrain may vary significantly from one excavation site to another.

[0006] Therefore, it is desirable to keep a historical record of the replacements made during the earth-moving work. However, those responsible for said record may forget to note down some of the replacements due to work overload or to any other reason, leading to unreliable data.

[0007] For this reason, it is desirable to have a system for automatically detecting when the replacement of said wear elements takes place.

Description of the Invention

[0008] The objective of the invention is to provide a method for determining replacements of the type indicated above, which allows solving the aforementioned problems.

[0009] This objective is achieved by means of a method of the type indicated above, characterized in that it comprises:

- monitoring said wear assembly to determine, over time, whether or not said wear assembly is in a state suitable for replacement of said wear elements; and
- monitoring said wear assembly to detect whether alert events take place, where each of said alert events is a candidate to an event of loss of one of said wear elements;

wherein, for each of said alert events, the method comprises the following steps:

- determining whether said wear assembly has been in said state suitable for replacement throughout at least an entire time window until said alert event has taken place; and
- if this is the case, determining that said alert event is an event of replacement of the wear element corresponding to said alert event, thereby determining that a replacement of said wear element has taken place.

[0010] In the context of the invention, wear assembly refers to a set of elements comprising at least one wear element and the support in which said at least one wear element is fixed, by way of non-exclusive example, an excavator shovel in which a plurality of teeth are fixed, although the invention can be applied to other types of wear elements, for example, those used in machines such as draglines, loaders, clamshells, shovels for cable buckets, and drills, among others possible examples. In that sense, an earth-moving machine may comprise several wear assemblies. The control means carrying out the method can be the same for all the wear assemblies, independent for each one, or any intermediate situation in which there are several control means and each controls one or more wear assemblies.

[0011] The method is, therefore, based on monitoring two main points. First, that the wear assembly is in a state suitable for replacement of the wear elements, i.e., a state allowing said wear elements to be replaced, for example, the machine is stopped and/or the wear elements are in a position within the operator's reach or in a position suitable for the automatic replacement of wear elements by dedicated replacement machinery. Said state will be different depending on the type of earth-moving machine and/or wear assembly, with some examples being set forth below. Second, the possibility of losing the wear elements (usually of the elements falling) is monitored. There are different proposals in the art for carrying out said monitoring of possible falls, for example, by means of proximity/presence sensors or using cameras monitoring the elements optically. When it is detected that a loss may have taken place, it is interpreted as an alert event which is a candidate to an event of loss. In fact, at present, such events are already used in the art to detect losses of wear elements, which is a technical problem different from the current one. The ways to detect said losses vary and different technical solutions are proposed, ranging from presence sensors to monitoring by means of cameras. Accordingly, the method of the invention uses a type of information that is already used in the art for other purposes (to detect losses of wear ele-

ments) and combines it with information relating to the state of the wear assembly, in order to thereby automatically determine whether the events, initially interpreted as possible losses, are actually replacements. To that end, faced with an alert event, it is checked whether the wear assembly has been in a state in which replacement with the corresponding wear element could be performed. The skilled person will understand that said alert event itself is not an alarm that appears directly on a console, a user warning, etc., the nomenclature refers to the occurrence of an event to be taken into consideration as it is a candidate to a loss of a wear element. Losses of wear elements usually take place when the machine is working, i.e., moving earth, so it is not a state suitable for replacement. In contrast, when a wear element is to be replaced, the wear assembly is placed in a position in which replacement can be carried out, for example, by stopping the machine such that said machine and the wear assembly are not in motion (although it will be possible to keep the engine running) and placing the wear assembly within the operator's reach. If it is verified that, when there is an alert event, the wear assembly has been in a state suitable for replacement for a minimum time, it is determined that the alert event actually corresponds to replacement and not to a loss. Replacement is, therefore, automatically detected and it is not necessary for anyone to note that said replacement has been carried out. This information can then be used to automatically determine the work parameters of the previous wear element (for example, the element type, work hours, installation, and replacement date, among others) and this data can be used for the purposes discussed above.

[0012] Based on the invention defined in the main claim, preferred embodiments the features of which are described in the dependent claims have been provided.

[0013] Preferably, said monitoring of said wear assembly to detect said alert events is performed by fall detection means comprising at least one fall sensor for each of said wear elements. By way of non-exclusive example, it is possible to provide accelerometers arranged inside the wear element, such that upon detecting a movement with certain characteristics, said movement is interpreted as a fall. For example, alternative embodiments in which said at least one fall sensor comprises a presence sensor, for example, a sensor based on the detection of a magnetic field between the wear element and the support, can also be provided, said fall sensor being configured to detect whether said wear element corresponding to said presence sensor moves away from said wear assembly. Likewise, other embodiments in which said fall detection means comprise a plurality of sensors, for example, accelerometers and a magnetic presence sensor, can also be provided.

[0014] Preferably, said wear assembly comprises a bucket, for example, an excavator bucket, provided with said wear elements attached thereto and in which said state suitable for replacement comprises said bucket not being in motion, which usually means that the earth-moving machine is not in motion either, although it does not have to be completely stopped. For example, it may be envisaged the possibility of keeping the engine running. For the case of an excavator bucket, the wear elements usually comprise excavator teeth, although they may also comprise tooth bars or adaptors assembled between the bucket and the teeth, as well as other interchangeable elements that wear off when used for earth-moving purposes. For example, the guards, which are placed between the adaptors or on the sides of the bucket, or the so-called wear caps, which are placed on the adaptors. Therefore, a necessary condition to consider that the wear assembly comprised in the bucket to is in a state suitable for replacement is that the bucket itself must not be in motion. It is possible to foresee different alternatives on the way of determining the absence of movement of the bucket. For example, by means of a motion sensor arranged in the bucket itself or in the articulated assembly of the support thereof, by means of reading information relating to the situation of the earth-moving machine, by means of optical systems, such as cameras, by means of motion sensors arranged on the wear elements, etc., even combinations thereof.

[0015] Preferably, said state suitable for replacement comprises said bucket being positioned in a predefined range of angles, such that a necessary condition for determining that the bucket is in a state suitable for replacement is that the bucket is inclined in a position in which access to the wear elements is possible. This condition can be combined with the preceding condition of the bucket not being in motion. Preferably, said predefined range of angles is between 15 and 45 degrees. Said angle is measured as an inclination with respect to the horizontal of the ground. The preferred lower limit is determined such that, for the specific type of wear assembly and machine, the wear element is kept in place without falling due to gravitational force. Likewise, the preferred upper limit is determined by the difficulty an operator may experience when substituting the element, which tends to increase as the angle increases. In both cases, it will depend on the characteristics of the machine and the wear assembly.

[0016] Preferably, said predetermined time window is between 3 and 5 minutes such that, when the wear assembly is in a state suitable for replacement for at least 3-5 minutes, it is determined that the alert events correspond to replacement. A too short time may result in a false replacement determination, while a too long time would mean that those events that should actually be considered as replacements would still be considered as candidates to events of loss.

[0017] The invention also relates to a system for determining replacements of wear elements of a wear assembly of an earth-moving machine, comprising monitoring means for monitoring said wear assembly configured to carry out the method described above.

[0018] The invention also relates to an earth-moving machine comprising said system for determining re-

placements.

[0019] The invention also covers other detail features illustrated in the detailed description of an embodiment of the invention and in the attached figures.

Brief Description of the Drawings

[0020] The advantages and features of the invention will become apparent from the following description in which preferred embodiments of the invention are described in a nonlimiting manner with respect to the scope of the main claim in reference to the figures.

Figure 1 is a schematic view of a wear assembly corresponding to an excavator bucket with wear elements in the form of teeth assembled on tooth bars.

Figure 2 is a schematic view of an earth-moving machine including a wear assembly according to the invention.

Figure 3 is a set of graphs showing the evolution of some information used in the method of the invention, adjusted to the same horizontal axis that represents time.

Detailed Description of Embodiments of the Invention

[0021] A first embodiment of the invention relates to an earth-moving machine of the type shown in Figure 2 having a system for determining replacements of wear elements 2 of a wear assembly 1 such as that shown in Figure 1 and Figure 2. The system includes the wear assembly 1 and monitoring means configured to carry out a method for determining replacements of said wear elements 2.

[0022] In particular, said method for determining replacements of the wear elements 2 of the wear assembly 1 of the earth-moving machine 3 includes monitoring the wear assembly 1 to determine, over time, whether or not said wear assembly 1 is in a state suitable for replacement 200 of said wear elements 2. The first graph of Figure 3 shows an example of the time evolution of said monitoring, where said graph is a simplified representation in which a high level corresponds to an active state not suitable for replacement, while a low level corresponds to an inactive state suitable for replacement.

[0023] In particular, in the first embodiment, the wear assembly 1 is an excavator bucket such as the one of Figure 1 with the wear elements 2 attached to said bucket. In that sense, for the state to be considered suitable for replacement, said bucket must not be in motion, which also means that the machine 3 is not in motion, although it is possible to keep the engine running. Likewise, the bucket must also be positioned in a predefined range of angles of between 15 and 45 degrees. In this first embodiment, the monitoring of the wear assembly 1 to determine whether or not it is in a state suitable for replacement 200 is performed by means of accelerometers arranged inside each of the wear elements, or in the bucket itself, although other embodiments, for example, using operational information from a control unit of the earth-moving machine 3 itself, can be foreseen.

[0024] The method also comprises monitoring the wear assembly 1 to detect whether alert events 100 take place, where each of said alert events 100 is a candidate to an event of loss of one of said wear elements 2. The three graphs in the lower portion of Figure 3 show simplified examples of the time evolution of the alert events associated with three of the wear elements 2. By way of example, the alert events are represented as peaks in the graphs.

[0025] In the first embodiment, the monitoring of said wear assembly 1 to detect said alert events 100 is performed by fall detection means, with a fall sensor for each of the wear elements 2. In particular, the fall sensor of each wear element 2 is a presence sensor which detects whether its corresponding wear element 2 moves away from the wear assembly 1. In this example, the presence sensor is a magnetic Hall effect sensor arranged on the tooth bar, which detects the presence of a magnetic field generated by a magnet arranged inside the corresponding tooth.

[0026] Every time an alert event 100 is determined, the method determines whether said wear assembly 1 has been in said state suitable for replacement 200 throughout at least an entire predetermined time window 300 up to the moment in which said alert event 100 has taken place. In the example, the predetermined time window 300 is 3 minutes, although other windows can be provided, among which those comprised between 3 and 5 minutes are preferred. If this is the case, the method determines that the alert event 100 is an event of replacement of the wear element 2 associated with said alert event 100. Therefore, it is determined that a replacement of said wear element 2 has taken place.

[0027] Using Figure 3 as an example, the first graph shows when the wear assembly 1 is in the state suitable for replacement 200, while the other graphs correspond to the evolutions of three of the wear elements 2. These graphs are generated as illustrative and simplified graphs. The second graph of Figure 3 shows an alert event 100 which is determined when the wear assembly 1 is in the state suitable for replacement 200 and has been in said state for a time longer than said predetermined time window 300. Therefore, the alert event 100 of the second graph is determined as a replacement of the wear element 2 corresponding to said graph.

[0028] In the example of the third graph of Figure 3, the second wear element 2 does not exhibit any alert event 100, and thus, no replacement is determined either.

[0029] In the example of the fourth graph, the third wear element 2 exhibits an alert event 100. However, said event occurs when the wear assembly is not in a position suitable for replacement 200. The graph shows a possi-

ble time evolution corresponding to the fall of the wear element 2 when the machine 3 is performing earth-moving operations. Given that the alert event 100 takes place when the wear assembly 1 has not been in the state suitable for replacement 200 for the predetermined time window 300, it is not determined that a replacement has taken place either.

[0030] Other embodiments of the invention sharing many of the features described in the preceding paragraphs are shown below. Accordingly, only the differentiating elements will be described hereinafter, while for the common elements reference is made to the description of the first embodiment.

[0031] In a second embodiment, the monitoring of said wear assembly 1 to detect the alert events 100 is performed by means of one or more cameras and an image analysis system allowing to identify the presence or absence of the wear elements 2.

Claims

1. Method for determining replacements of wear elements (2) of a wear assembly (1) of an earth-moving machine (3), **characterized in that** said method comprises:

   - monitoring said wear assembly (1) to determine, over time, whether or not said wear assembly (1) is in a state suitable for replacement (200) of said wear elements (2); and
   - monitoring said wear assembly (1) to detect whether alert events (100) take place, where each of said alert events (100) is a candidate to an event of loss of one of said wear elements (2);

   wherein, for each of said alert events (100), the method comprises the following steps:

   - determining whether said wear assembly (1) has been in said state suitable for replacement (200) throughout at least an entire predetermined time window until said alert event (100) has taken place; and
   - if this is the case, determining that said alert event (100) is an event of replacement of the wear element (2) corresponding to said alert event (100), thereby determining that a replacement of said wear element (2) has taken place.

2. Method according to claim 1, **characterized in that** said monitoring of said wear assembly (1) to detect said alert events (100) is performed by fall detection means comprising at least one fall sensor for each of said wear elements (2).

3. Method according to claim 2, **characterized in that** said at least one fall sensor comprises a presence sensor configured to detect whether said wear element (2) corresponding to said presence sensor moves away from said wear assembly (1).

4. Method according to claim 1, **characterized in that** said monitoring of said wear assembly (1) to detect the alert events (100) is performed by means of at least one camera and an image analysis module, configured to identify the presence or absence of said wear elements (2).

5. Method according to any one of claims 1 to 4, **characterized in that** said wear assembly (1) comprises a bucket provided with said wear elements (2) attached thereto, and wherein said state suitable for replacement (200) comprises said bucket not being in motion.

6. Method according to claim 5, **characterized in that** said state suitable for replacement (200) comprises said bucket being positioned in a predefined range of angles.

7. Method according to claim 6, **characterized in that** said predefined range of angles is between 15 and 45 degrees.

8. Method according to any one of claims 1 to 7, **characterized in that** said predetermined time window (300) is between 3 and 5 minutes.

9. System for determining replacements of wear elements (2) of a wear assembly (1) of an earth-moving machine (3), **characterized in that** it comprises monitoring means for monitoring said wear assembly (1) configured to carry out the method according to any one of claims 1 to 8.

10. Earth-moving machine (3) comprising a system for determining replacements according to claim 9.

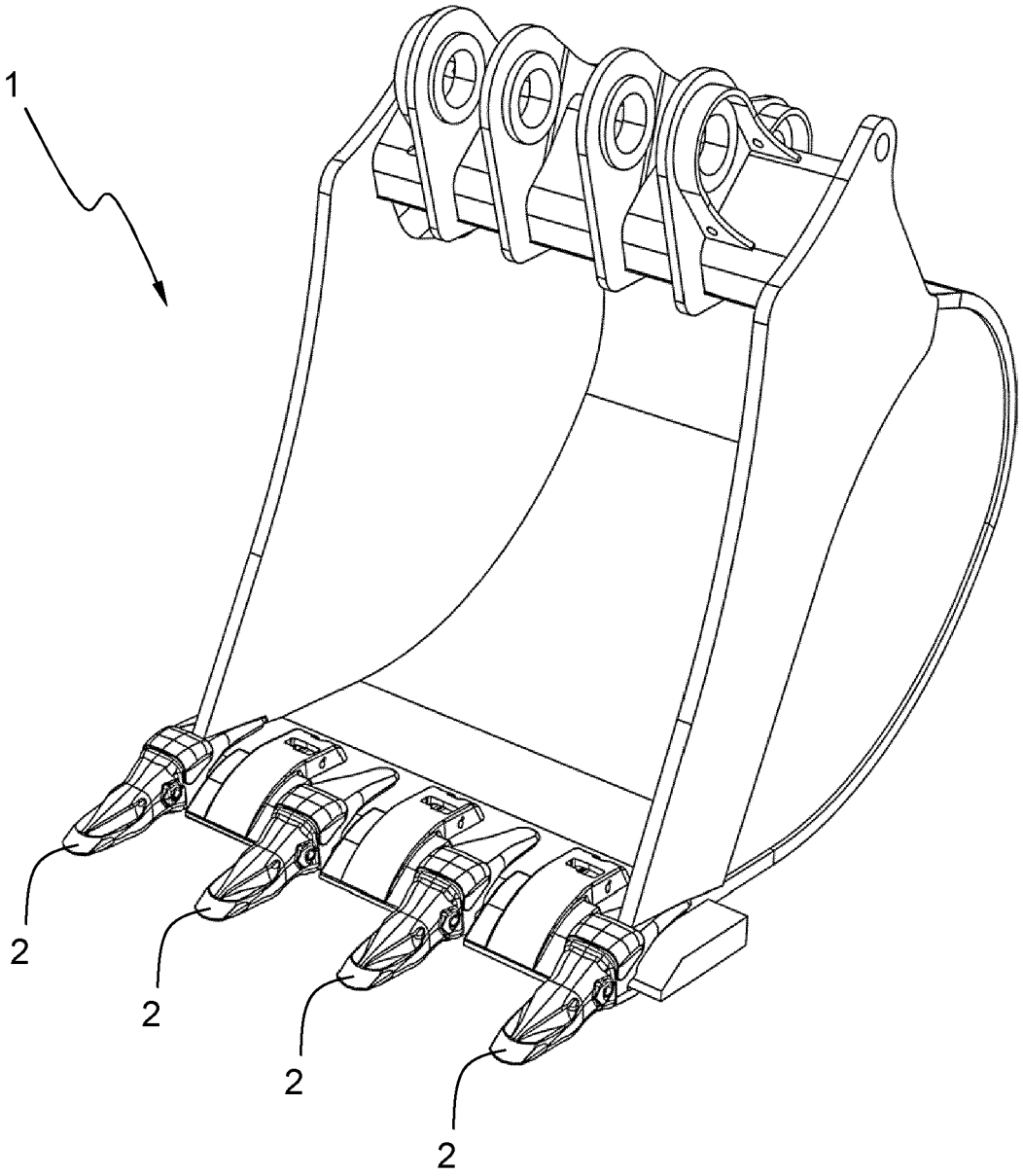

FIG. 1

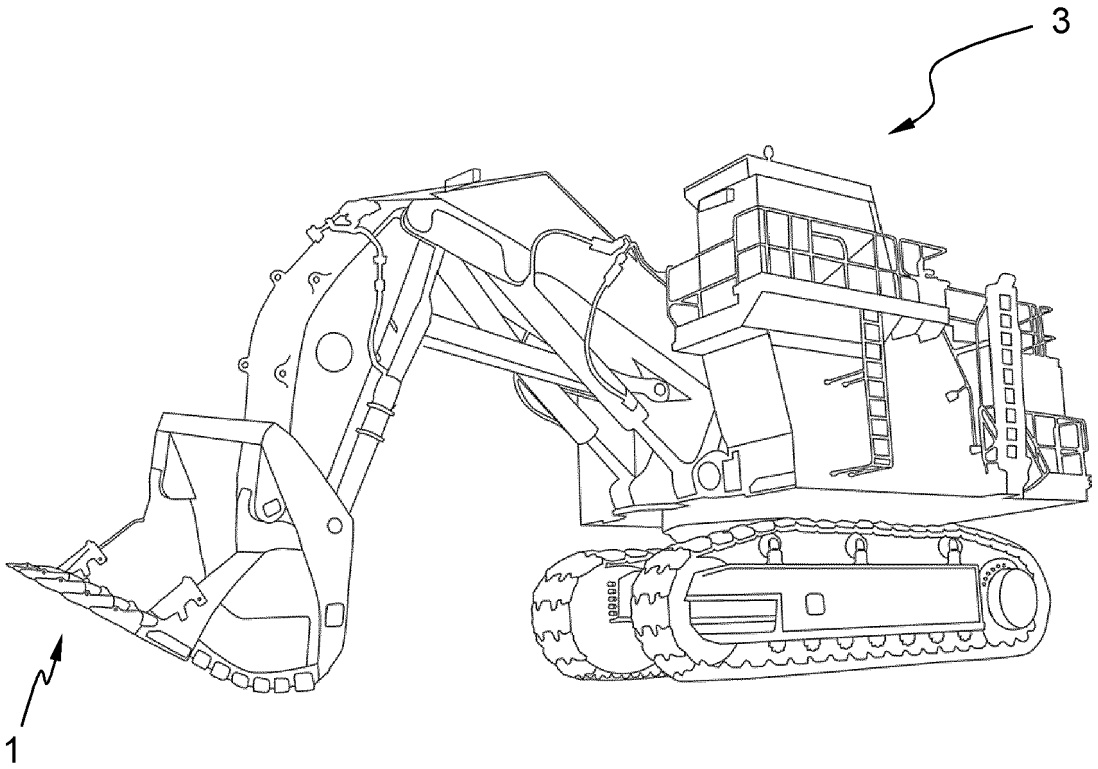

FIG. 2

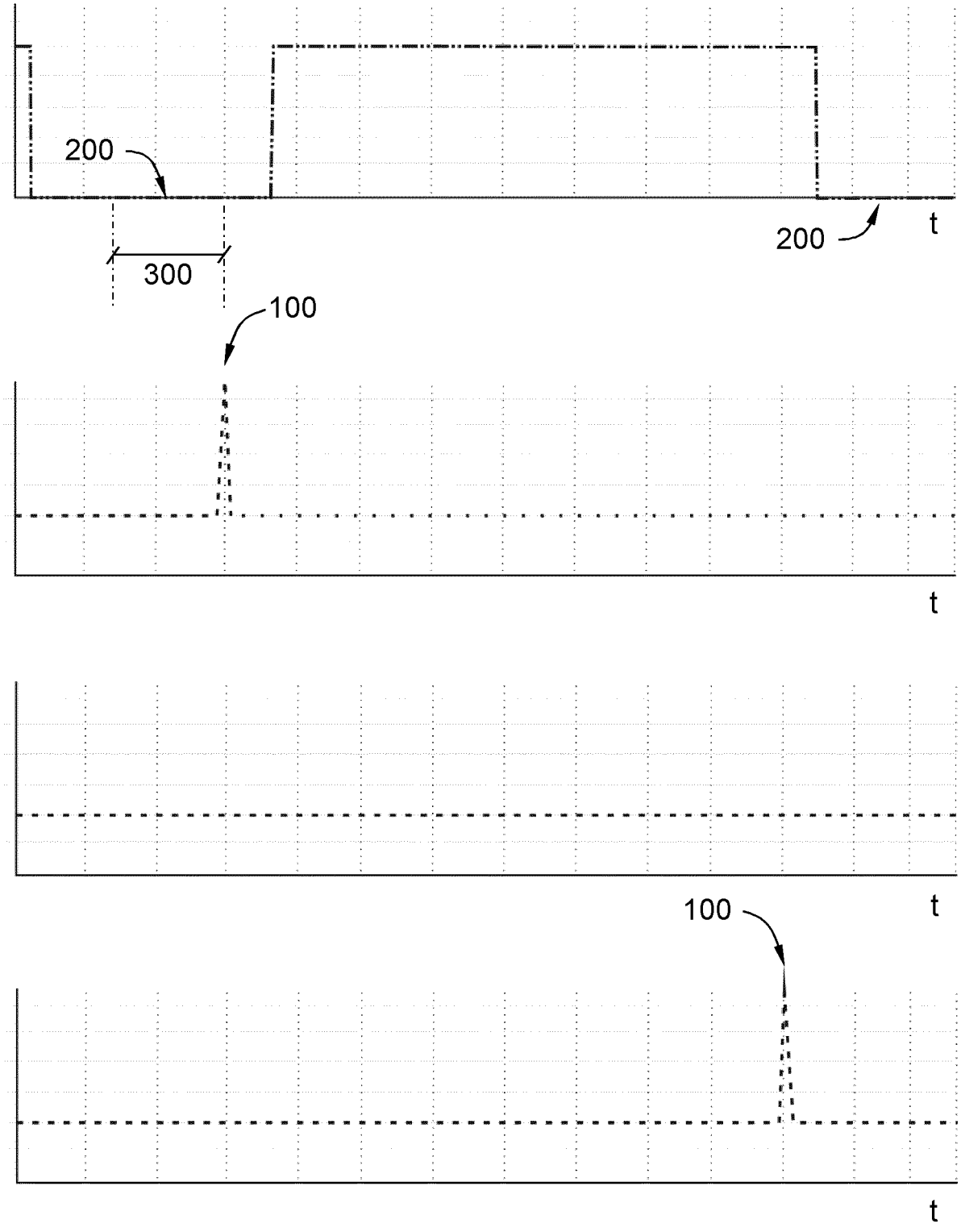

FIG. 3

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EUROPEAN SEARCH REPORT

Application Number
EP 23 38 2121

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TECHNICAL FIELDS SEARCHED (IPC)

E02F

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	26 June 2023	Dreyer, Christoph

CATEGORY OF CITED DOCUMENTS

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