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(71) Applicant: **Ideko, S.Coop.**
20870 Elgoibar Guipuzcoa (ES)

(72) Inventors:
- **LANZAGORTA BENGOCHEA, Jose Luis**
  20870 Elgoibar (Guipuzcoas) (ES)
- **AIZPURUA MAESTRE, Iratxe**
  20870 Elgoibar (Guipuzcoas) (ES)
- **RUIZ VAZQUEZ, Paula**
  20870 Elgoibar (Guipuzcoas) (ES)
- **BARRENECHEA AZPEITIA, David**
  20870 Elgoibar (Guipuzcoas) (ES)

(74) Representative: **Plasseraud IP**
66, rue de la Chaussée d'Antin
75440 Paris Cedex 09 (FR)

(54) **MACHINING DEVICE AND METHOD**

(57) The invention relates to a machining device and method. The machining device (100) comprises a machining tool (103), a support (101) configured for receiving a part (200) to be machined, and a control unit configured for controlling at least one operating parameter of the device (100). The device (100) comprises an inspection head (105) with at least one eddy current sensor configured for producing eddy currents on the surface of the part (200) during machining. The inspection head (105) is connected to the control unit. The control unit is configured for acting on at least one operating parameter of the device (100) if it detects a variation of the eddy current distribution obtained as a result of microstructural changes on the surface of the part (200) greater than a predetermined threshold value.

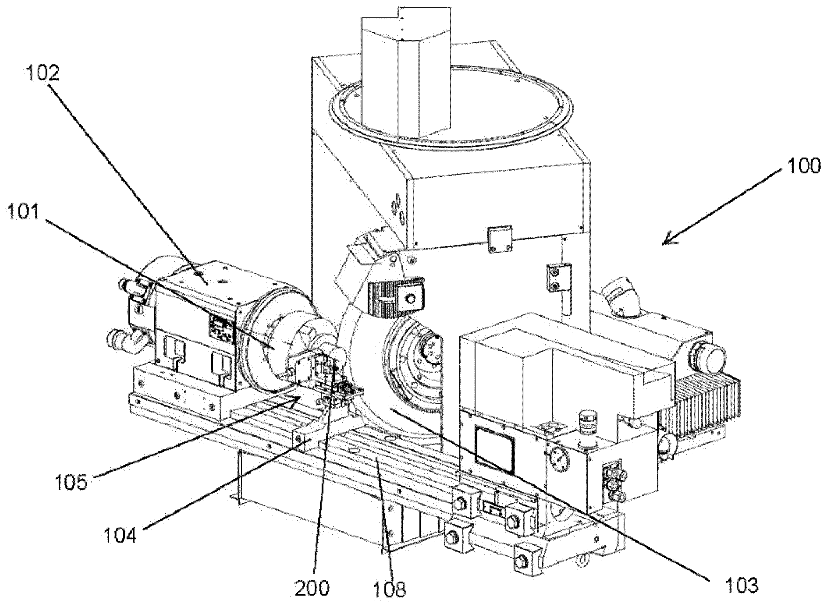

Fig. 1

Processed by Luminess, 75001 PARIS (FR)

Description

Technical field

[0001] The object of the present invention relates to a machining device and method for machining parts, particularly applicable to the grinding of steel parts.

[0002] The machining device and method object of the present invention allow obtaining parts with mechanical properties adapted to the service parameters required for the part, minimizing machining errors, and therefore decreasing the number of parts that must be discarded and/or disposed of after machining due to the appearance of thermal damage comprising microstructural changes, burns, white layer, cracks, etc., on the part.

[0003] The machining device and method object of the present invention are applicable in the industry dedicated to the manufacture of high-precision metal parts.

State of the art

[0004] In the manufacture of high-precision parts which require very demanding dimensional tolerances (such as crankshafts, camshafts, gears, etc.), a surface machining step is required for correcting the dimensions and the surface finish of the parts. One of these machining operations is the grinding of parts. To perform this grinding, a machine comprising a support configured for receiving a part to be machined and a rotary grinding wheel to apply grinding is used. Therefore, once the part to be ground is fixed on the support, a grinding wheel with an abrasive surface is applied to the surface of the part to be machined. The grinding wheel is rotated at a certain rotational speed and, in turn, the part to be machined can also be subjected to a rotational speed.

[0005] In the machining operation, there are several variables which affect the appearance of defects in the part. One of the variables lies in the behavior of the grinding wheel when it is subjected to wear, where flat faces, resulting in the appearance of structural changes which generate defects in the part, may be generated, for example. There are other variables which affect the structural change of the part such as cooling, rotational speed of the part, speed of cutting advancement of the grinding wheel, etc.

[0006] Therefore, it is common for a type of defect known as surface "burn" or grinding "burn" to appear in part grinding operations, a common name assigned to the thermal damage (metallurgical change) that may occur on the contact surface of the part due to the high temperatures reached during the process. Grinding burn can soften or harden the surface layers of the material depending on the process parameters, significantly altering the mechanical properties of the component. When the temperature at the ground surface is higher than the tempering temperature but lower than the austenitizing temperature (Ac3), the microstructure undergoes a tempering process, reducing surface hardness. This defect is called grinding burn.

[0007] When surface defects appear on machined parts due to grinding burn, the part must be discarded and disposed of since it is no longer useful to fulfill the specific purpose for which it was designed. Therefore, it is important to detect the parts in which this grinding burn has appeared because this discarding and disposal of parts implies a significant economic cost for the precision metal part manufacturing industry.

[0008] A technique known as "acid inspection" is often used for detecting grinding burn. This technique consists of the application of an acid on the surface of the machined part and subsequent surface examination. The technique allows "revealing" defects characteristic of the surface burn on the parts. This technique cannot be automated and depends on the subjectiveness and experience of the operator.

[0009] Another technique used for detecting grinding burn is surface analysis by means of eddy currents. By applying a variable magnetic field emitter, usually using a "pencil" type probe, the surface of the machined part is examined. The passage of alternating current through the probe generates an alternating magnetic field which, in the vicinity of a conductive material, induces eddy currents in the material. The presence of surface defects in the material (cracks, pores, microstructural changes, burns) causes a variation in the eddy current distribution in the material. This variation produces a signal in the eddy current equipment, in the probe itself, or in a receiving probe which in turn produces a signal in the equipment interpreted as a surface defect indicator.

[0010] The use of pencil type probes is commonly applied in grinding operations in which the size of the width of the grinding wheel and the inspection area of the pencil type probe is similar. However, there is a greater challenge in the face grinding process given that the ground surface covers a greater width, so performing inspection with a pencil type sensor would not be sufficient to cover the entire ground area. Likewise, another physical limitation exists in the case of using several pencil type probes for the inspection of an elevated area (similar to that affected during grinding) given that the distance between the coils of each probe must ensure total coverage of the ground surface, which is complex due to the physical dimensions of the pencil type probes and the resulting signal processing. In addition, in the flat face grinding process, burn can possibly be generated both in the inner area of the component and in the outer area. Therefore, it is necessary to control the entire ground area in real time.

[0011] The operators in charge of the machining and subsequent inspection of the parts attempt to learn from the defective cases to modify the operating parameters of the grinding machines so that they can anticipate and try to avoid surface burn and disposal of the parts, whether by means of using the acid inspection technique or by means of the eddy current technique. However, the proposed changes are based solely on experience without there being any objective system on which to control the part and process.

[0012] However, to this day, metal part machining operations, and more specifically grinding operations, constitute deeply experimental techniques that ultimately depend heavily on the degree of expertise of the operators handling the grinding machines. For this reason, it is difficult to predict the appearance of surface burn on machined parts, and it is therefore difficult to prevent the appearance of said burn, as well as to predict the number of parts that will end up being discarded as a result of the appearance of said surface burn.

Object of the invention

[0013] In order to solve the aforementioned drawbacks, the present invention relates to a machining device and method.

[0014] The machining device object of the present invention comprises a machining tool for grinding parts (for example, a grinding wheel), a support configured for receiving a part to be ground, and a control unit configured for controlling at least one operating parameter of the device.

[0015] The machining device object of the present invention comprises, in a novel manner, an inspection head with an eddy current sensor with at least one coil configured for producing eddy currents on the surface of the part during machining and for detecting a variation of the eddy current distribution obtained as a result of microstructural changes on the surface of the part. The induction of eddy currents is controlled by the control unit of the device which will be in charge of causing the passage of an alternating current for inducing eddy currents on the surface of the part.

[0016] The inspection head is connected to the control unit of the device, with the control unit of the device being configured for acting on at least one operating parameter of the device in response to detecting a variation of the eddy current distribution greater than a predetermined threshold value. The electronics for eddy current induction and detection and the electronics for changing the machining parameters of the device can be arranged together or independently.

[0017] When the variation of the eddy current distribution exceeds the mentioned predetermined threshold value, it may be indicative of the beginning of the appearance of grinding burn in the part.

[0018] As a result of the machining device described above, it is possible to detect the appearance of a grinding burn in-process, i.e., during the part machining (grinding) operation, and not only after the end of the machining. In other words, the device of the invention includes in one and the same device both a grinding machine and a burn detection device which allows said in-process inspection.

[0019] When a predetermined threshold value is exceeded, this detection allows the control unit of the machining device of the invention to act on at least one operating parameter of the machining device during the machining itself without having to stop the machine, in order to minimize and/or reverse the grinding burn effect that may be appearing. In other words, said threshold value anticipates the appearance of burns in the part, modifying the parameters which change the operating conditions to prevent burn completely or to allow burn with values that do not affect the structural characteristics required for the use of the part. Therefore, said threshold value is considered a pre-burn safety factor which allows modifying the parameters to prevent said burn.

[0020] According to a preferred embodiment of the machining device, the inspection head comprises a sensor array (sensor with several coils) which allows covering a larger inspection area controlling a larger surface with a single sensor and reducing the inspection time. In particular, a sensor array in one and the same assembly with several electronically controlled coils as a single unit. This is particularly applicable when machining is performed on a flat face of the part, given that the sensor array can cover a maximum area of the flat face of the part in order to detect possible irregularities indicative of a grinding burn.

[0021] According to a design option, the inspection head comprises a sensor array support end with a surface in correspondence with the geometry of the part. This arrangement allows the sensor array to be able to adapt to the surface of the part, for example, to the curvature of the axis of the part, and to thereby cover points that may be inaccessible for inspection.

[0022] However, both machining and detection by means of the inspection head can also be applied on a curved (e.g., cylindrical) face instead of on a flat face of a part to be machined.

[0023] Preferably, the machining device comprises control means for controlling the separation distance between the inspection head and the part. This is particularly useful given that the dimensions of the part (of its surface) gradually change during the machining operation.

[0024] These control means for controlling the separation distance between the inspection head and the part may comprise a spring configured for ensuring a constant distance between the inspection head and the surface of the part.

[0025] The machining device may also comprise approaching means between the support for the part and the machining tool.

[0026] As mentioned above, the control unit of the device is configured for acting on at least one operating parameter of the device.

[0027] These operating parameters can be one or more of the following:

- a rotational speed of the support for the part;
- a rotational speed of the machining tool;
- a speed of advancement of the tool towards the part.

- a diamond coating on the machining tool;
- a dose of cooling fluid applied on the part, and;
- the approach or separation between the part and the machining tool.

[0028] Other grinding variables which modify the microstructure of the part can be included.

[0029] In an alternative embodiment, it is envisaged that the control unit is configured to completely stop the machining operation of the machining device in order to effect a change of parameters that cannot be performed during the process itself, such as the case of applying a diamond coating on the surface of the machining tool, in order to correct irregularities (e.g., flat faces on the surface of the tool or grinding wheel) which may negatively affect the part to be machined. This change of process parameters could be carried out individually or together with the variation of at least one of the aforementioned parameters.

[0030] According to the invention, the approaching means for moving the inspection head closer to the part move in a guided manner on a machining guide corresponding to the machining guide of the machining device, for example, the guide of a grinding machine, such that the sensor is moved closer to the part in a manner perpendicular to the surface to be machined during machining inspection. A high precision is obtained without external elements such as pistons that are commonly used in the known solutions, the positional repeatability of which when transitioning to the inspection start position is low due to the clearance generated throughout the cycles.

[0031] For positioning the sensor, the part head guide itself is used, which ensures a micrometric positioning accuracy and a sensor-part parallelism tolerance of under a hundredth. In this way, both the geometric positioning and the adjustment of the distance of the head with the part, performed during startup, have a very high repeatability, favoring optimal operation of the head and measurement reliability.

[0032] Additionally, said approaching means comprise positioning means which position the sensor in the plane perpendicular to the movement of the approaching means. They allow for greater precision during inspection.

[0033] According to a feature of the invention, the sensor of the inspection head is a sensor array covering a maximum area corresponding to an area such that, with the rotation of the part at each turn, the tool sweeps the entire surface to be machined, with the surface to be machined being a flat face of a part of revolution. Preferably, this maximum area corresponds to the area covered by the grinding wheel on the flat face of the part, i.e., in correspondence with the width of the surface between the outer diameter and the inner diameter of said flat face.

[0034] As mentioned above, the present invention also relates to a machining method (e.g., a grinding method for grinding metal parts by means of a grinding wheel).

[0035] The machining method object of the present invention comprises arranging a part on a support of a machining device, and machining a surface of the part by means of a machining tool of the device.

[0036] The machining method object of the present invention comprises in a novel manner:

- generating eddy currents on the surface of the part being machined by means of an inspection head of the device comprising an eddy current sensor, i.e., while the part is being ground, currents are induced in the part by the control unit (electronics) which controls the sensor and applies a variable magnetic field to the sensor;
- detecting, by means of the inspection head, a variation of the eddy current distribution obtained as a result of microstructural changes on the surface of the part, and sending the values of said variation to a control unit of the device, and;
- acting, by means of the control unit, on at least one operating parameter of the device if it is detected that the variation of the eddy current distribution obtained as a result of microstructural changes on the surface of the part exceeds a predetermined threshold value.

[0037] This method allows an in-process inspection, i.e., at the same time as the grinding of the part, and with the advantage that by identifying the burn threshold value, it is possible to act immediately on the grinding parameters to prevent burn in the entire part. This therefore entails time and material savings since no defective parts are discarded.

[0038] The action performed by the control unit on at least one operating parameter of the machining device may comprise at least one of:

- reducing or increasing a rotational speed of the support for the part;
- reducing or increasing a rotational speed of the machining tool;
- reducing or increasing the speed of advancement of the tool towards the part;
- increasing or reducing the flow rate of cooling fluid applied to the part, and;
- causing the approach or separation between the part and the machining tool through the approaching means between the support and the machining tool.

[0039] Acting on other grinding variables which modify the microstructure of the part can be included.

[0040] According to a possible embodiment of the machining method, when it is detected that the variation of the eddy current distribution obtained as a result of microstructural changes on the surface of the part exceeds a predetermined threshold value, the method comprises:

- stopping a rotation of the machining tool and/or a rotation of the support for the part;
- causing the separation between the part and the machining tool through the approaching means between the support and the machining tool;
- applying a diamond coating on a surface of the machining tool;
- causing the approach between the part and the machining tool through the approaching means between the support and the machining tool;
- optionally further modifying at least one of the aforementioned parameters, and;
- resuming a rotation of the machining tool and/or a rotation of the support for the part.

[0041] In this last embodiment, it is possible to stop the machining device in order to act on grinding parameters which require stopping the device, such as applying a diamond coating. This type of action of applying a diamond coating with the device stopped can be combined with the simultaneous modification of another one of the aforementioned parameters, and said change of parameters can even be carried out before or after stopping the machine.

[0042] According to another aspect of the invention, in order to detect when the predetermined threshold value is exceeded, the machining method uses a sensor array obtaining an eddy current distribution for the entire machining process of the part, with the eddy currents being processed to be shown in a single image (by means of C-Scan) representing the current distribution obtained for the entire surface to be machined swept along the maximum area covered by the sensor array as a function of time. The data display obtained is therefore a color map based on the position of the coils of the sensor array over the course of the machining process, detecting when the variation of the eddy current distribution obtained exceeds the predetermined burn threshold value. The C-scan image is intended to provide an uncomplicated visual representation of the process in order to provide the inspection result to the operator. To that end, it uses a configurable color code to differentiate burn-free zones from burned zones. In particular, a color code has been defined and is shown in Figure 7 in gray scale to view the inspection result. The light gray color represents the burn-free areas, the dark gray color represents the areas close to the threshold value, and the black color represents the areas that have exceeded the threshold value. In addition, the aforementioned representation allows knowing the location of the burn in the part, linking the coil number to its position in the part, which allows different process parameters to be adjusted in order to prevent the appearance of burn.

Description of the figures

[0043] The following figures have been included as part of the explanation of at least one embodiment of the invention.

Figure 1 shows a schematic perspective view of a possible embodiment of the machining device object of the invention, in which a part to be machined is arranged.

Figure 2 shows a schematic side view of the machining device of Figure 1.

Figure 3 shows a schematic detail view of a possible embodiment of the inspection head of the machining device.

Figure 4 shows a graph of the evolution of the eddy current signal over the course of a machining operation.

Figure 5 shows a block diagram of the machining method of the invention.

Figure 6 shows a detail view of the positioning means of the approaching means of the machining device object of the invention.

Figure 7 shows a representation map (C-Scan) of the distribution of eddy currents obtained over the course of the process for grinding a flat face of a machined part as a function of position.

Detailed description of the invention

[0044] As mentioned above, the present invention relates to a machining device (100) and method.

[0045] Figure 1 and Figure 2 schematically show the machining device (100).

[0046] The machining device (100) comprises a support (101) configured for receiving and fixing a part (200) to be machined. The support (101) can be configured to rotate by means of a motor (102) and to imprint a rotation on the part (200) to be machined.

[0047] The device (100) comprises a machining tool (103) which, for the practical example shown in the figures, is a grinding machine with a grinding wheel (103). The machining tool (103) is configured to rotate such that the part (200) is worn away by abrasion. A control unit will be in charge of performing the machining according to initial machining parameters previously determined for the part (200) to be ground. This is the conventional method used in a grinding machine.

[0048] Moreover, the device (100) comprises an inspection head (105) arranged close to the support (101). As can be seen in more detail in Figure 3, the inspection head (105) comprises a fixing support or approaching means (104) for the fixing thereof to the machine and one or more magnetic field generators associated with one or more sensors.

[0049] The detection head (105) has several coils for generating eddy currents on the surface of the part (200). These coils can be arranged or grouped according to different configurations or alignments (or "arrays") for the purpose of producing a specific eddy current configuration on the part (200) to be inspected, such that the inspection is facilitated and the eddy current density is the most suitable for performing the inspection.

[0050] An inspection area (106) of the inspection head (105) is shown shaded in Figure 3. This inspection area (106) is the sensor array.

[0051] As can be seen, said shaded area corresponding to the sensor array (106) covers, with a plurality of coils, a maximum area which corresponds to the width of the surface machined by the tool or grinding wheel (103) between a maximum diameter and a minimum diameter of the flat face of the part (200).

[0052] Therefore, during machining, the inspection head (105) is configured for generating, with the sensor array (106), a magnetic field directed towards a surface of the part (200) such that the control unit controls the electronics of the equipment to cause alternating current to pass through the sensor array (106) such that it generates an alternating magnetic field which, in the vicinity of the part (200), induces eddy currents on the surface of said part (200) as it is made of a conductive material. When there are microstructural variations such as burns, cracks, pores, etc., they will be detected by the inspection head (105) when the sensor array (106) detects a variation in the eddy current distribution in the material producing a signal in the equipment.

[0053] Therefore, the machining device (100) can be considered as the conjunction of a conventional machine with an inspection device, such that it is possible to inspect the part (200) to detect burns therein at the same time that the machining takes place (in-process).

[0054] As mentioned above, the control unit of the device (100) is configured for controlling one or more operating parameters related to the machining of the part (200). Said parameters being those involved in grinding such as: a rotational speed of the machining tool (103), a rotational speed of the support (200) for the part (101), actuation of the approaching means, a speed of advancement of the tool (103) towards the part (200), and flow rate dosing of cooling fluid (e.g., coolant) on the surface of the part (200).

[0055] The inspection head (105) is connected to the control unit. The control unit is configured for receiving and analyzing the signals coming from the inspection head (105).

[0056] If the control unit detects that the signals coming from the inspection head (105) indicate a variation of the eddy current signal on the surface of the part (200) greater than a predetermined threshold, the control unit produces a first control action for controlling one or more operating parameters of the device (100).

[0057] This threshold is determined through specific tests forcing the excessive generation of burn in the part. Another system to establish this limit is to use standard parts with reference burns obtained by means of techniques other than grinding, such as laser, for example.

[0058] This threshold value takes into account a safety factor, whereby ensuring that the microstructure of the part is not damaged and that the generation of burn is anticipated.

[0059] The following strategies can be performed as strategies adopted for determining said threshold value:

- In a first strategy, a standard part is defined by generating artificial burns with defined depth, using the laser technique to that end.

[0060] The sensor is passed through the standard part and the maximum voltage is determined. Then, if said voltage or higher is obtained when inspecting the part once it is ground, the value obtained during the in-process inspection is considered the limit burn threshold.

- In another strategy, in-process inspections are performed during consecutive grinding passes. Subsequently, the parts after each pass are inspected by acids and the maximum voltage is established by comparison. If that voltage or higher is obtained when inspecting the part once it is ground, the value obtained during the inspection is considered as the limit burn threshold.
- Another novel strategy carried out is the strategy which is performed by means of a continuous test, accumulating wear on the grinding wheel. The maximum value of the current curve is sought and this value is established as the in-process limit burn threshold. Figure 4 shows a practical example of obtaining the limit burn threshold, depicting the curve of the eddy current sensor, in which no burn occurs in areas A and B, with a smaller amplitude of the variations than in areas C and D in which burn does occur. From this graph, it can be seen that the maximum voltage is V = 4 V, if a safety factor of 0.5 V is applied thereto, $V_{threshold}$ = 3.5 V is obtained.

[0061] The limit burn threshold value is thereby obtained, where other techniques of setting a threshold value that defines the limit of permissible microstructural variations so that the burn does not influence the mechanical characteristics of the part (200) can be used.

[0062] Therefore, upon detecting that the signal coming from the inspection head (105) indicates a value greater than the predetermined threshold, the control unit acts during the machining process on one of the aforementioned grinding parameters without stopping the machine.

[0063] Preferably, in order to detect when the variation of the eddy current distribution obtained exceeds the predetermined threshold value, it is envisaged for the eddy current distribution obtained by the sensor array (106) of the inspection head (105) for the entire machining process of the flat face of the part (200), to be processed and represented in a single image, known as a C-Scan. This image represents a map of current distribution obtained for the entire surface to be machined swept along the maximum area covered by the sensor array (106) as a function of time, determining the time and position at which the pre-burn microstructural change defined by the predetermined threshold value occurs. Figure 7 shows, in a gray scale representation, the representation of the grinding of the flat face of the part (200) up to the appearance of burn, with the horizontal axis representing the position as a function of the circumferential distance traveled by the sensor array (106) and the vertical axis representing the position of the values obtained between the inner diameter and the outer diameter of the flat face of the part. In this way, it can be seen how the burn starts in the outer area of the part in the area shaded with a darker gray, such that, during the grinding process, when a threshold value is detected prior to the appearance of said burn, the control unit performs the corresponding changes of parameters.

[0064] Eventually, the control unit may stop the machining operation completely. This may occur, for example, for the purpose of performing a parameter change operation which requires stopping the machine, such as applying a diamond coating on the machining tool (103), in order to improve and/or correct the surface characteristics of the machining tool (103) (e.g., to eliminate flat faces that may have appeared on the surface of the machining tool (103) and that could damage the surface of the part (200) during machining).

[0065] According to a design option as shown in Figure 3, the inspection head (105) may comprise a support end (107) for the sensor array (106) with a surface configured for adapting to an axis of the part (200) to be machined, in this case a curved surface in correspondence with the axis of the part (200), such that the sensor covers the entire flat surface. This flat surface corresponds to the maximum area of the width of the part (200) covered by the grinding wheel (103), such that the entire surface to be machined is swept at each turn.

[0066] The device (100) also comprises control means for controlling the separation distance between the inspection head (105) and the part (200). These control means for controlling the separation distance between the inspection head (105) and the part (200) may consist of a spring (not depicted) which allows maintaining a constant distance of the inspection head (105) with respect to the surface of the part (200), taking into account the dimensional variation (wear) that the surface of the part (200) sustains during machining/grinding operations.

[0067] Furthermore, as can be seen in Figure 1, the approaching means (104) serving as a support for the inspection head (105) comprising the sensor array (106) move in a guided manner on a guide (108) corresponding to the machining guide of the grinding machine. This configuration allows a high precision in the approach positioning of the sensor array (106) in the direction perpendicular to the flat face to be machined of the part (200).

[0068] Additionally, for greater precision, as can be seen in Figure 6 preferably, the approaching means comprise positioning means (109) preferably in the form of a contact tip with a micrometric head with knurling, which position the sensor array (106) in the plane perpendicular to the guided movement of the approaching means (104). It is envisaged that such a micrometric head with knurling will allow the position to be quantified to centesimal accuracy.

[0069] As can be seen in the block diagram of Figure 5, the machining method of the invention is exemplified, in which it can be schematically seen how the device (100) is made up of both a machining system and an inspection system. First, machining parameters are used for performing the grinding process carried out by the process electronics of the control unit, and at the same time an in-process inspection is performed by means of the inspection electronics of the control unit. If the value obtained in the inspection exceeds the predetermined threshold value, the control unit will modify the operating parameters by establishing new parameters which prevent burns. If, on the contrary, the detected value is less than the threshold value predetermined as the burn limit, the grinding process continues.

[0070] In this way, this machining process successfully reduces production times and prevents the disposal of parts by preventing burns during the grinding process itself which could result in defective parts.

Claims

1. A machining device (100) comprising a machining tool (103), a support (101) configured for receiving a part (200) to be machined, and a control unit configured for controlling at least one operating parameter of the device (100), **characterized in that** it comprises an inspection head (105) with an eddy current sensor with at least one coil configured for producing eddy currents on the surface of the part (200) during machining, wherein the inspection head (105) is connected to the control unit of the device (100), the control unit of the device (100) being configured for acting on at least one operating parameter of the device (100) in response to detecting that a signal coming from the inspection head (105) is indicative of a variation of the eddy current distribution obtained as a result of microstructural changes on the surface of the part (200) greater than a predetermined threshold value.

2. The machining device (100) according to any of the preceding claims, **characterized in that** the sensor of the inspection head (105) is a sensor array (106).

3. The machining device (100) according to the preceding claim, **characterized in that** the inspection head (105) comprises a support end (107) of the sensor array (106) with a surface in correspondence with the geometry of the part (200).

4. The machining device (100) according to any of the preceding claims, **characterized in that** it comprises control means for controlling the separation dis-

tance between the inspection head (105) and the part (200).

5. The machining device (100) according to claim 4, **characterized in that** the control means for controlling the separation distance between the inspection head (105) and the part (200) comprise a spring configured for ensuring a constant distance between the inspection head (105) and the surface of the part (200).

6. The machining device (100) according to any of the preceding claims, **characterized in that** it comprises approaching means (104) between the support (101) for the part (200) and the machining tool (103).

7. The machining device (100) according to any of the preceding claims, **characterized in that** the control unit of the device (100) is configured for acting on at least one of the following operating parameters of the device (100):

   - a rotational speed of the support (101) for the part (200);
   - a rotational speed of the machining tool (103);
   - a speed of advancement of the tool (103) towards the part (200);
   - a diamond coating on the machining tool (103);
   - a dose of cooling fluid applied on the part (200), and;
   - an approach or separation between the part (200) and the machining tool (103).

8. The machining device (100) according to claim 6, **characterized in that** the approaching means (104) of the inspection head (105) move in a guided manner on a machining guide (108) of the machining device (100) for moving the sensor closer to the part (200) during machining inspection.

9. The machining device (100) according to the preceding claim, **characterized in that** the approaching means (104) comprise positioning means (109) which position the sensor in the plane perpendicular to the movement of the approaching means (104).

10. The machining device (100) according to any of the preceding claims, **characterized in that** the sensor of the inspection head (105) is a sensor array (106) covering a maximum area corresponding to an area such that the tool (103) sweeps the entire surface to be machined with the rotation of the part in each turn, the surface to be machined being a flat face of a part (200) of revolution.

11. The machining device (100) according to the preceding claim, **characterized in that** the machining device (100) is a grinding machine which rotates the part (200) for machining it, the machining tool (103) being a rotary grinding wheel.

12. A machining method comprising arranging a part (200) on a support (101) of a machining device (100), and machining a surface of the part (200) by means of a machining tool (103) of the device (100), **characterized in that** it further comprises:

   - generating, by means of an inspection head (105) of the device (100), a density of eddy currents towards the surface of the part (200) being machined;
   - detecting, by means of the inspection head (105), a variation of the eddy current distribution obtained as a result of microstructural changes on the surface of the part (200), and sending the values of said variation to a control unit of the device (100), and;
   - acting, by means of the control unit, on at least one operating parameter of the device (100) if it is detected that the variation of the eddy current distribution obtained as a result of microstructural changes on the surface of the part (200) exceeds a predetermined threshold value.

13. The machining method according to claim 12, **characterized in that** acting, by means of the control unit, on at least one operating parameter of the machining device (100) comprises at least one of:

   - reducing or increasing a rotational speed of the support (101) of the part (200);
   - reducing or increasing a rotational speed of the machining tool (103);
   - reducing or increasing the speed of advancement of the tool (103) towards the part (200);
   - increasing or reducing a dose of cooling fluid applied on the part (200), and;
   - causing the approach or separation between the part (200) and the machining tool (103) through the approaching means (104) between the support (101) and the machining tool (103).

14. The machining method according to claim 12 or 13, **characterized in that**, if it is detected that the variation of the eddy current distribution obtained as a result of microstructural changes on the surface of the part (200) exceeds a predetermined threshold value, the method comprises:

   - stopping a rotation of the machining tool (103) and/or a rotation of the support (101) for the part;
   - causing the separation between the part (200) and the machining tool (103) through the approaching means (104) between the support (101) and the machining tool (103);
   - applying a diamond coating on a surface of the

machining tool (103);
- causing the approach between the part (200) and the machining tool (103) through the approaching means (104) between the support (101) and the machining tool (103);
- optionally further modifying at least one of the parameters of claim 13, and;
- resuming a rotation of the machining tool (103) and/or a rotation of the support (101) to continue machining the part.

15. The machining method according to any one of claims 12 to 14, **characterized in that** a sensor array (106) according to claim 10 is used and the eddy current distribution obtained for the entire machining process of the part (200) is processed and shown in a single image representing the current distribution obtained for the entire surface to be machined swept along the maximum area covered by the sensor array (106) as a function of time.

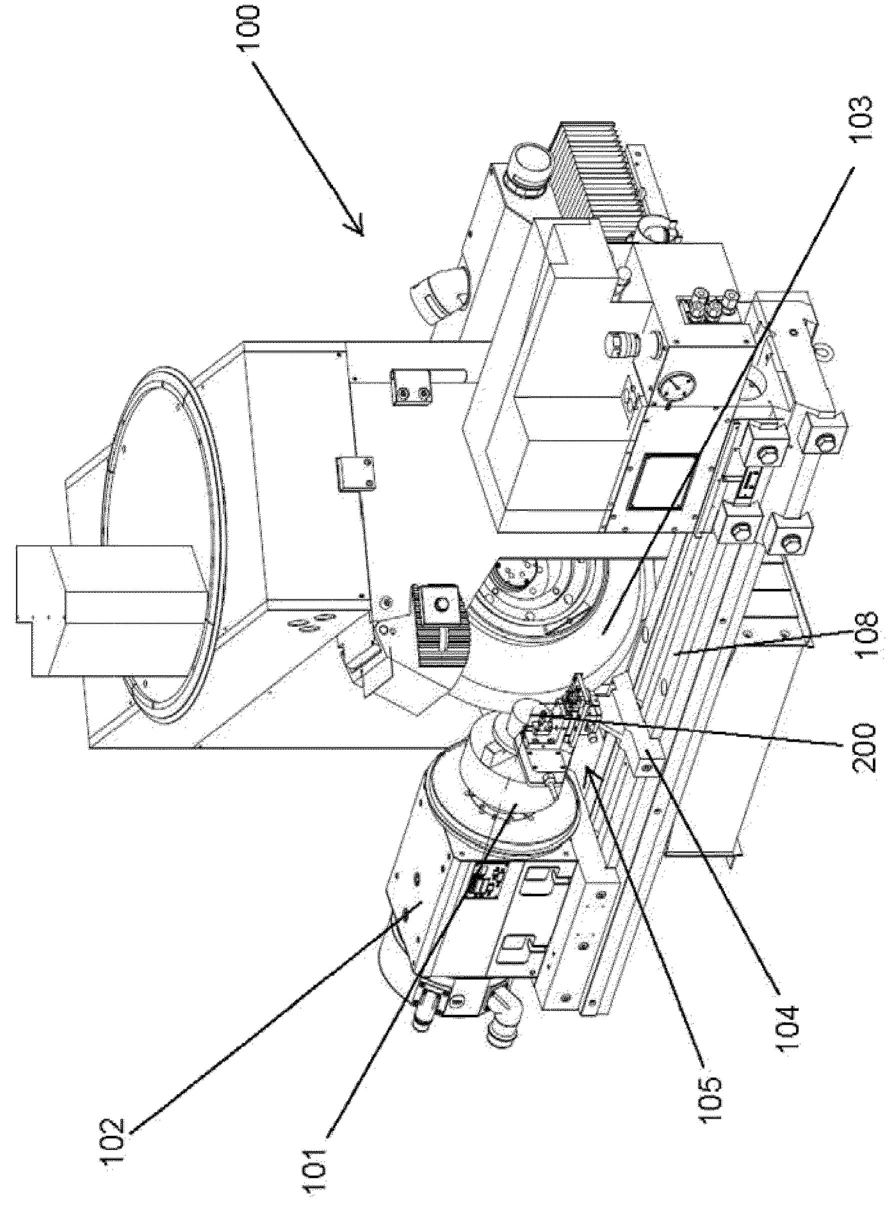

Fig. 1

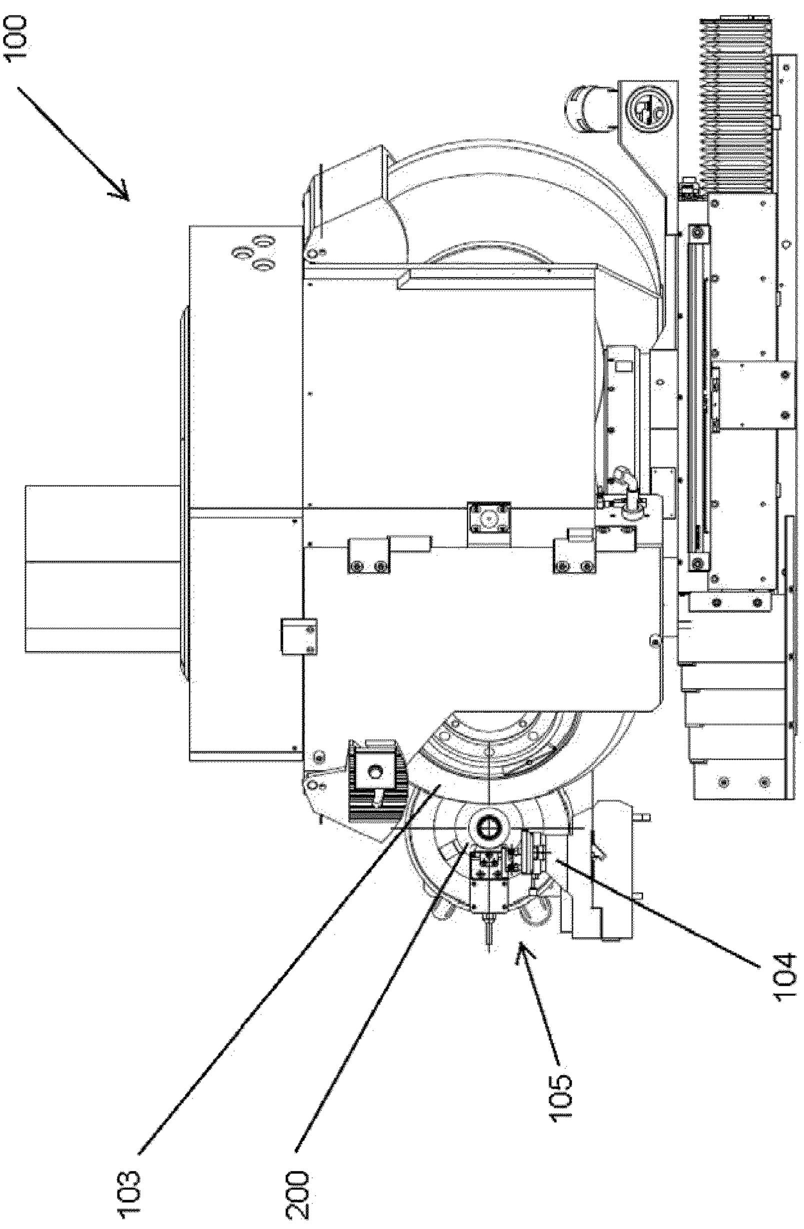

Fig. 2

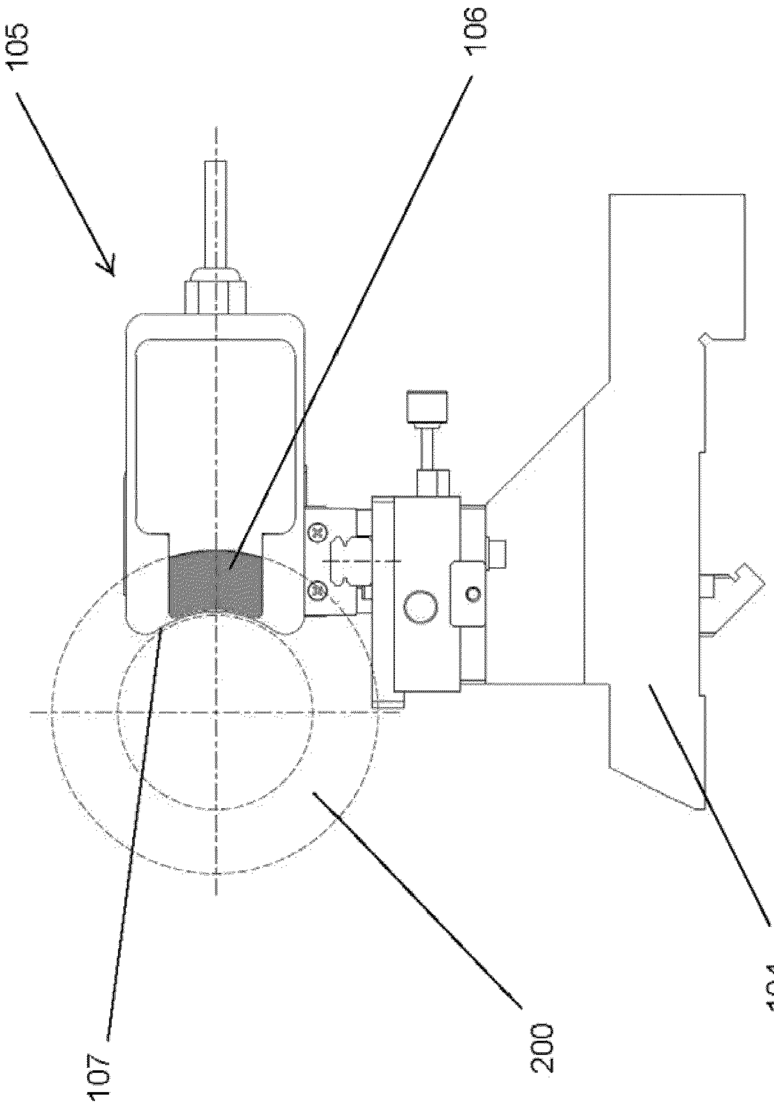

Fig. 3

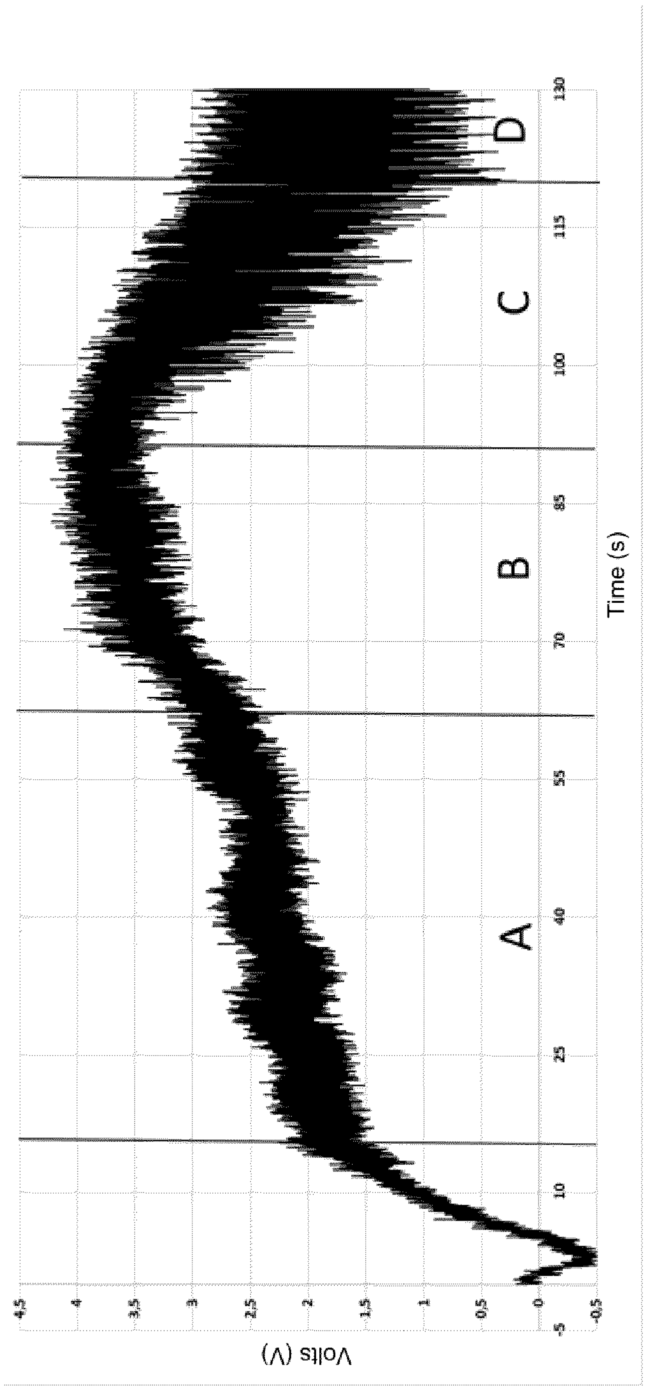
Volts (V)
4,5
4
3,5
3
2,5
2
1,5
1
0,5
0
-0,5
-5
10
25
40
55
70
85
100
115
130
Time (s)
A
B
C
D

Fig. 4

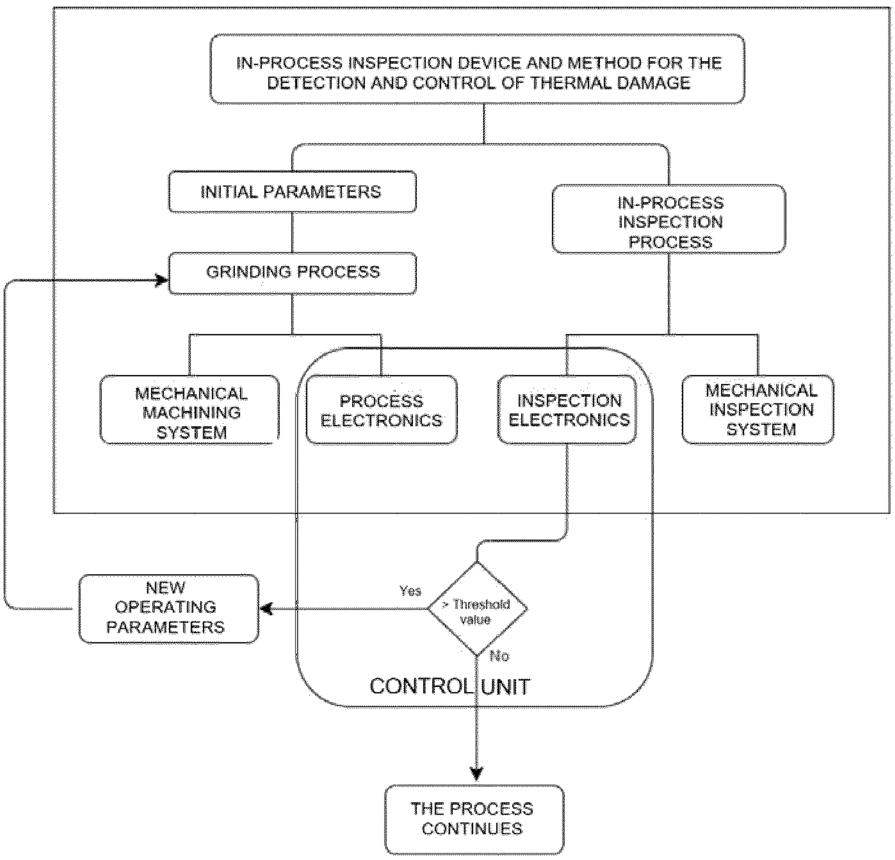
IN-PROCESS INSPECTION DEVICE AND METHOD FOR THE DETECTION AND CONTROL OF THERMAL DAMAGE
INITIAL PARAMETERS
IN-PROCESS INSPECTION PROCESS
GRINDING PROCESS
MECHANICAL MACHINING SYSTEM
PROCESS ELECTRONICS
INSPECTION ELECTRONICS
MECHANICAL INSPECTION SYSTEM
NEW OPERATING PARAMETERS
Yes
> Threshold value
No
CONTROL UNIT
THE PROCESS CONTINUES

Fig. 5

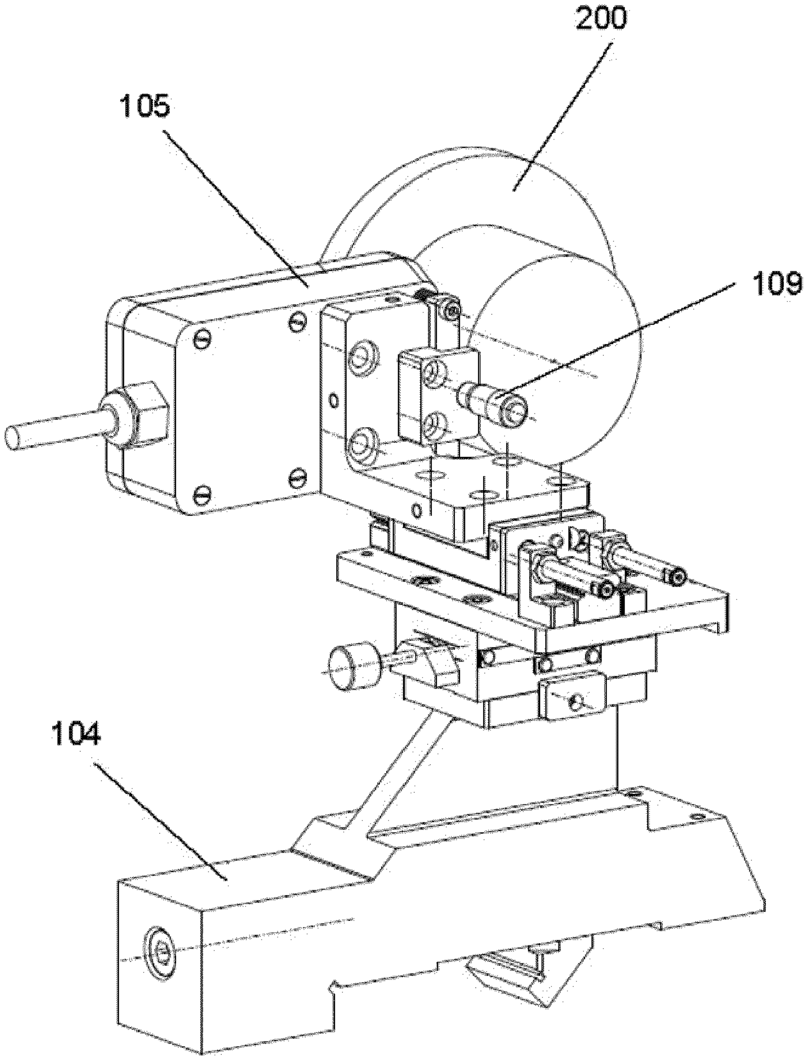

FIG. 6

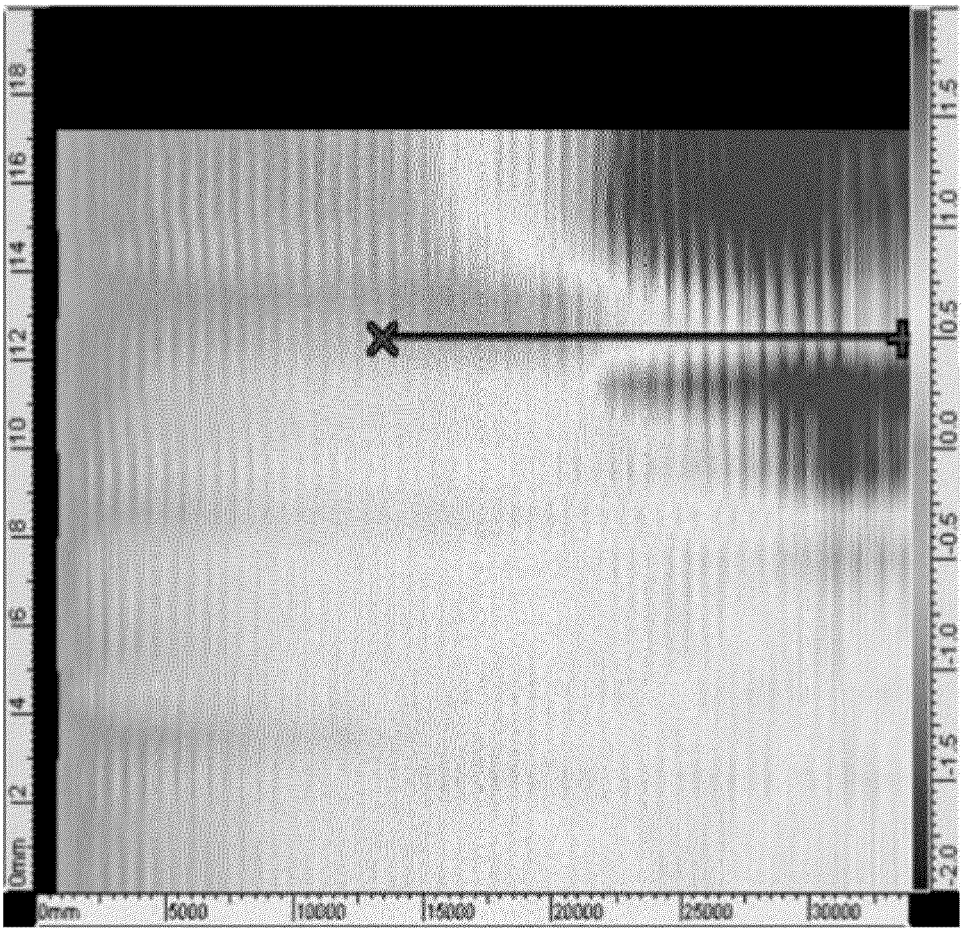
0mm
2
4
6
8
10
12
14
16
18
0mm
5000
10000
15000
20000
25000
30000
1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5
-2.0

FIG. 7

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EUROPEAN SEARCH REPORT

Application Number
EP 22 38 3033

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B24B
B23Q

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
Munich	10 March 2023	Antolí Jover, Jordi

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