(19) LE GOUVERNEMENT
DU GRAND-DUCHÉ DE LUXEMBOURG
Ministère de l'Économie

(11) N° de publication : **LU100513**

(12) **BREVET D'INVENTION** **B1**

(21) N° de dépôt: LU100513

(22) Date de dépôt: 07/11/2017

(51) Int. Cl.:
B28B 11/12, G01B 21/04, G01N 21/88, G06T 7/00, B28D 1/00, B28D 1/30, B28D 7/00

(30) Priorité:
07/11/2016 BE BE2016/5832

(43) Date de mise à disposition du public: 30/07/2018

(47) Date de délivrance: 26/11/2018

(73) Titulaire(s):
Declercq Stortbeton nv – 8790 Waregem (Belgique)

(72) Inventeur(s):
DECLERCQ Filip – 8790 Waregem (Belgique)

(74) Mandataire(s):
BRANTSANDPATENTS – 9051 GAND (Belgique)

(54) **Method and device for processing a three-dimensional, concrete object.**

(57) In a first aspect, the present invention describes a method for processing a three-dimensional concrete object, for example for processing a concrete stairs element having granulates, comprising processing the object by means of an active processing head for that purpose provided in a holder on a robotic arm, characterized in that the processing is done by means of a true model, made up based on measured, positional information with respect to one or more reference points located on the object. In a second aspect, the invention relates to a processing device for processing a three-dimensional concrete object, comprising a robotic arm and a holder for a processing head and/or measuring head, provided at the robotic arm, characterized in that at least one measuring module is provided, suitable for measuring positional information with respect to one or more reference points located on the object to be processed.

METHOD AND DEVICE FOR PROCESSING A THREE-DIMENSIONAL, CONCRETE OBJECT

TECHNICAL FIELD

The present invention relates to a method and device for processing a three-dimensional concrete object.

STATE OF THE ART

Processing an object from concrete is usually labor-intensive activity, which significantly increases the cost. In addition, it is often also a dangerous activity. First of all, the danger lies in the potentially large size and mass of the object to be processed. Secondly, fast-moving machines are usually used such as milling machines and polishing machines. Exposure to the dusty environment may also be dangerous, especially for the lungs. In addition, concrete dust is alkaline, which can lead to further damage to the lungs, as well as damage to eyes and skin.

One possible solution is to perform the processing of concrete objects as much as possible by means of an automated device. Optimally, this device requires only minimal or no human intervention. For the processing of complex objects, such a device must at least have sufficient information regarding the position, orientation, shape and dimensions of the object to be processed. This is necessary for determining the required movements of the processing head during the operation. In principle, a three-dimensional model, such as a CAD drawing, suffices to display all information regarding the shape and dimensions of the object.
For custom made, (concrete) objects, such a model is often available; in fact, a model or plan was usually drawn on which the object was cast. This model is referred to as "the theoretical model" in what follows. However, a theoretical model does not take into account inaccuracies associated with the casting process, which is specific to concrete objects. In many cases, the operation must also be done very accurately, to less than one millimeter. The theoretical model is then not suitable for the correct determination of the necessary movements of the processing head.
The present invention aims at finding a solution to at least one of the above-mentioned problems.

SUMMARY OF THE INVENTION

To this end, the invention provides, in a first aspect, a method of processing a three-dimensional concrete object according to claim 1. The method comprises processing the object by means of an active processing head provided for that purpose in a holder to a robotic arm. In particular, the operation is done on the basis of a true model, based on measured, positional information regarding one or more reference points located on the object. By performing the operation based on the true model, the device takes into account the actual shape and dimensions of the object. This allows a more accurate operation of the object.
In a second aspect, the present invention describes a processing device for processing a three-dimensional concrete object according to claim 17. The processing device comprises a robotic arm and a holder for a processing head and/or measuring head provided with the robotic arm. In particular, at least one measurement module is provided suitable for measuring positional information with respect to one or more reference points located on the object to be processed. The device thus provides the ability to measure and charge true positional information. The advantage of this is that the device is suitable for performing a more accurate operation of the object.

DESCRIPTION OF THE FIGURES

Figure 1 shows a two-dimensional front view of an embodiment of the processing device with a robotic arm hangingly mounted on a travelling crane.

Figure 2 shows a three-dimensional perspective of an embodiment of the robotic arm with a milling head.

Figure 3a shows a three-dimensional perspective of an embodiment of the method during polishing of a concrete stairs element having granulates.

Figure 3b shows a three-dimensional perspective of an embodiment of the method during milling of a trailing element with granules.

DETAILED DESCRIPTION OF THE INVENTION

The present invention relates to a method and device for processing a three-dimensional concrete object.

Unless otherwise defined, all terms used in the description of the invention have also technical and scientific terms, the meaning as commonly understood by those skilled in the art of the invention. For a better review of the description of the invention, the following terms are explicitly explained.

"A", "the" and "it" refer in this document to both the singular and plural unless the context clearly assumes otherwise. For example, "a segment" means one or more than one segment.

When "approximately" or "round" in this document is used with measurable magnitude, parameter, duration or moment, etc., variations are meant to be +/- 20% or less, preferably +/- 10% or less, more preferably +/- 5% or less, more preferably +/- 1% or less, and even more preferably +/- 0.1% or less than and of the cited value, to the extent that such variations are applicable in the described invention. However, it should be understood that the value of the quantity using the term "about" or "round" is specifically disclosed.

"Comprise", "comprising", and "comprises" and "comprised of" as used herein are synonymous with "include", "including", "includes" or "contain", "containing", "contains" and are inclusive or open-ended terms that specifies the presence of what follows e.g. component and do not exclude or preclude the presence of additional, non-recited components, features, elements, members, steps, known in the art or disclosed therein.

In a first aspect, the invention relates to a method of processing a three-dimensional concrete object. The method comprises processing the object by means of an active processing head for this purpose provided with a holder on a robotic arm. In particular, the operation is done on the basis of a true model, based on measured, positional information regarding one or more reference points located on the object. This has the advantage that the actual shape and dimensions of the object are taken into account when processing the object. In a preferred embodiment of the method, the concrete object is cast into a mold prior to processing, determined on the basis of a theoretical model for the object and followed by curing of the concrete. According to a non-limiting example, the object is cast into a shape that lends itself to the intended shape for the object after processing. The object then only requests a surface treatment, which is carried out according to the present method. According to another non-limiting example, the object is cast into a shape which, where possible, lends itself to the intended shape for the object after processing, except for the aspects difficult to cast. For example, a typically hard to cast recess or hole is only applied retrospectively according to the present method. A third, non-limiting example combines the two previous examples.

According to an alternative method, the required movements of the robotic arm are completely determined based on the theoretical model for the object. However, the actual object is often insufficiently consistent with its theoretical model. For example, in case of a concrete object, errors may occur during the casting process. Certain dimensions are too small, in the order of a millimeter, because too little concrete was used or because the lowering of the concrete when shaking was not compensated for. On the other hand, certain dimensions are too big because too much concrete was used in casting. Inaccuracies may also be due to inaccurate adjustment or fabrication of the formwork. Finally, pouring concrete is also a fairly rough process, with an accuracy of the order of millimeters. The finish of the object, however, often requires a much higher accuracy. This is especially the case for custom-made items. In a non-limiting example, each layer should be milled off a layer of 3.75 mm to 4.25 mm. It is then necessary to set up a real plan that maps the actual objects to be processed of the object. This can be based on measured, positional information regarding one or more reference points located on the object. It is advantageous that the present method provides this.

In a first preferred embodiment of the method, the true model is made, based on the measured positional information. This does not take into account the theoretical model for the object. Preferably, the method then comprises measuring a point cloud of sufficiently high accuracy and density. This point cloud describes the position of a large number of points located on the surface of the object. The point cloud also allows reconstruction of this surface with sufficiently high accuracy. Higher accuracy can be obtained by measuring a higher density point cloud. A possible true model for the object, or for its part to be edited, is then a finite element model, based on the point cloud. In an alternative true model, the point cloud is simplified into a composition of a limited number of idealized facets which are flat and/or curved according to a cone surface, a cylinder surface and/or a spherical surface. This simplification always takes into account the required accuracy of the true model for the intended operation; Each facet has an optimal overlap with the corresponding part of the point cloud and describes that part sufficiently accurately. As set forth above, the true model according to this preferred embodiment is constructed purely based on the measured positional information. This has the advantage that this embodiment of the method can also be applied to objects for which there is no theoretical model or at least no digital version of the theoretical model which could readily be read by the processing device.

In an alternative preferred embodiment of the method, the true model is made, based on the theoretical model in combination with the measured positional information. According to a further, preferred embodiment, the true model is drawn up as refinement of the theoretical model. Preferably, there is a digital version of the (three-dimensional) theoretical model, read in a first step by the processing device. In a second step, the position and orientation of the three-dimensional theoretical model relative to the object is determined.

- A first, non-limiting way to determine this position and orientation is to measure a full point cloud located on the surface of the object and then position and orient the theoretical model so that its overlap with this point cloud is optimal is.
- A second, non-limiting way to determine this position and orientation is to determine the position of at least three well-chosen reference points on the object, for which the corresponding reference points in the theoretical model are well-known. This is sufficient for determining the position and orientation of the object.

In a non-limiting preferred embodiment of the method, the theoretical model describes the surface of the object based on the composition of a limited number of idealized facets which are flat and/or curved according to a cone surface, a cylinder surface and/or a spherical surface. In that case, the true model is preferably composed of corresponding facets which position, orientation and/or curvature differs slightly from those in the theoretical model, insofar as it is necessary to optimize the overlap of the true model with the object. The facets are then tested against the point cloud describing the surface of the object and being measured beforehand. Each facet is adapted to describe the corresponding point cloud sufficiently accurately. The latter point cloud is not necessary of high density; In principle, the orientation of a flat facet can be determined by measuring only three reference points on that facet, not on the same line. Preferably, however, more than three reference points are measured, with a good spread over the facet. In this way, local aberrations are averaged, which increases the accuracy of the measurement. For curved facets, a point cloud of more than three reference points is preferably measured. In many cases, the true model should also describe the edge of the facets. For facets with straight edges and vertices, preferably at least all vertices are measured. This is sufficient for the description of an object composed of flat facets. In an alternative, non-limiting preferred embodiment of the method, the theoretical model, optimally positioned and oriented relative to the object, is used as a true model.

The operation as described in the present method usually involves removing material on the surface of the object. By way of a first, non-limiting example, the method allows to eliminate inaccuracies due to the casting process. According to another, non-limiting example, the method is used to make the surface of the object smoother or to make it even more rough. According to a third non-limiting example, the method can be used to visualize an internal structure of the material, for example, for aesthetic reasons, by removing a layer of thickness 1 mm from the surface. The theoretical model always proposes the intended object prior to the surface processing. Preferably, the theoretical model sets the object flat after casting, prior to surface treatment, without charging the inaccuracies associated with the casting process. The theoretical model thus already takes account of the mentioned operation; Optional material may be provided at certain areas of the surface, which will be removed during the operation of the object. The true model for the object is similar to the theoretical model, in that it takes into account the removal of material on the surface. However, the true model takes into account the actual shape and dimensions of the object. Preferably, the true model thus takes into account inaccuracies due to casting process with concrete objects. This data therefore determines the specific interpretation of the "optimal overlap" between the true model and the object to be processed, which in some cases depends on the intended operation. Suppose, by way of a first, non-limiting example, that a layer of minimum thickness d should be removed from a (theoretical) plane facet. The real facet includes local imperfections; At these locations a layer of thickness greater than d must be removed. A point cloud is measured, of sufficiently high density to adequately describe the irregularities. The corresponding facet in the true model is now determined such that the "overlap" with the point cloud is maximum. In this specific case, this means that the said facet is then parallel to the plane that best describes the point cloud. In addition, the facet includes that point, which represents the deepest local unevenness. For example, the plane describing the point cloud best is determined by the least squares method for predetermined systems of equations. The operation, as performed by the robot head, will remove all the material to a distance d under the real facet. During the operation, it is therefore taken into account that in certain places, the real object to be processed may extend beyond the real facet described above. Suppose, by way of a second, non-limiting example, that the intended operation is to remove all imperfections from the object and then polish the object. The true model comprising one or more facets is then made in the same way as above, extended to curved facets. For example, the curvature of convoluted facets is enlarged and these hollow facets are reduced, so that only the deepest imperfections are located on the surface of the true model. This is again the "model of optimal overlap" with the object. Then all the material is removed to the true model, after which the surface is polished until smooth. The amount of material removed during polishing is usually negligible.

The true model just described is always an idealization of the object, into a composition of flat facets and/or facets curved according to a cone surface, a cylinder surface and/or a spherical surface. In an alternative preferred embodiment of the method, the true model of the object is a rigorous, three-dimensional model. By way of non-limiting example, this model is a finite element model, based on a measured point cloud. The object is then processed by the Robotic arm with processing head, based on this model. In a first further preferred embodiment, the robotic arm operates to a specified three-dimensional model object after processing. In an alternate further preferred embodiment, the operation comprises removing a layer of even and specified thickness of area of the object. Instead or in addition, the surface of the object is polished smoothly.

In a preferred embodiment of the method, the positional information is measured at least in part by means of a measurement module provided for that purpose by the robotic arm. This has the advantage that the position of the reference points can be read automatically by the processing device, without the intervention of people. In a further preferred embodiment, the reading of reference points occurs based on the theoretical model for the object. By way of non-limitative preferred embodiment, only a few well-chosen reference points are mapped, for which the position is known in the theoretical plan. The real plan is then drawn up from the theoretical plan, taking into account the actual position of the reference points.

In a further preferred embodiment of the method, the positional information is measured at least in part by means of a measurement module separate from the robotic arm. After all, the version where the robotic arm is equipped to measure both the object and the object can be possibly inefficient; At any time, only one of the two processes can continue. The use of a stand-alone read-in module has the advantage that the robotic arm can be optimally utilized for processing objects. The objects are then read in advance with a separate reading module, apart from the robotic arm. The true model of the object, as formulated by the detached measurement module, then describes the shape and dimensions of the object, and possibly its position and orientation relative to a fixed coordinate system. If the object is moved, for example to the robotic arm, only the position and orientation relative to a fixed coordinate system must be re-determined. According to a preferred embodiment, however, as described below, the robotic arm is hangingly mounted on a travelling crane and is the robotic arm that is moved toward the object, using the travelling crane. In that case, the position of the robotic arm relative to the fixed coordinate system of the object should always be known by the automated device. By way of non-limiting example, this can be done by regularly reading at least 3, well-chosen reference points on the object during the operation.

In an alternative preferred embodiment of the method, the positional information relating to one or more reference points located on the object is determined partly by means of a measurement module for that purpose to the robotic arm and partly by means of a measuring module separate from the robotic arm.

When measuring the position of a reference point, on the one hand, the position of the reference point is determined relative to the measurement module and on the other

hand the position of the measurement module relative to an coordinate system is fixedly connected to the object. In this way, the position of the reference point relative to an coordinate system fixed to the object can be determined. This is of particular importance when working with a manual, mobile measurement module or with a module connected to a mobile robotic arm. When moving the object, the (imaginary) fixed coordinate system is also moved with the object. In a first non-limiting example, the automated device also knows at any time during the processing, position and orientation of the processing head relative to this fixed coordinate system. With this information, the automated device then calculates the position and orientation of the processing head relative to the object. According to another non-limiting example, the automated device calculates the position and orientation of the processing head relative to the object from the position of at least 3 selected reference points to the object, which is read regularly during the operation.

In a preferred embodiment of the method, the robotic arm is computer controlled, wherein said computer exchanges positional information with at least one measurement module. In a further preferred embodiment, the same computer is suitable for compiling the true model for the object from the measured positional information and/or the theoretical plan. The fully automated exchange and processing of data aims at avoiding human intervention as much as possible. Of course, this is advantageous, as processing of concrete objects can be dangerous. First of all, the danger lies in the potentially large size and mass of the object to be processed. Secondly, it is usually used with fast-moving machines such as milling machines and polishing machines. In addition, exposure to the dusty environment may also be dangerous, especially for the lungs. In addition, concrete is alkaline, which can lead to further damage to the lungs, as well as damage to eyes and skin.

In a further preferred embodiment, the robotic arm is computer controlled and the positional information, at least in part, is manually entered and/or adapted in said computer. It is advantageous that there is the possibility of manually entering and/or adjusting measurement values. In a non-limiting example, a solid model is prepared for a milled concrete object prior to polishing. However, when milling, enclosed cavities are released on the surface. If one of the measurement points is located in such a cavity, the real plan might be very distorted, especially when working with a limited number of reference points. However, if the strong deviating value is noted, this measurement can be manually entered or modified in the computer. Before or after polishing, the holes are then filled with filler material, for example with concrete.

In a preferred embodiment of the method, at least one measurement module comprises a laser distance meter, which is based on the principle of triangulation measurement and/or travel time measurement. Preferably, a laser distance meter based on the triangle measurement principle is used to measure objects of maximum size less than 10 meters. The advantage of this type of laser distance meter is the combination of potentially very fast measurement and potentially very high accuracy; Some devices are capable of measuring more than 1000 reference points per second, with accuracy higher than 1 mm. In further preference, at least one measurement module comprises a 3D scanner comprising the laser distance meter. A 3D scanner captures the three-dimensional environment, as well as determining the distance from each point to the device. The advantage of this is that a three-dimensional point cloud is automatically obtained. In an alternative embodiment, the distance to a limited number of well-chosen reference points is measured. In a further preferred embodiment of the method, each measurement module comprises a laser distance meter and in a more preferred embodiment, each measurement module comprises a 3D scanner comprising a laser distance meter.

In a further or alternative preferred embodiment, at least one measurement module comprises one or more acoustic sensors, mechanical sensors and/or sensors of any other type suitable for measuring distances and/or positions. Among other (waterproof) mechanical sensors have the advantage over laser distance meters that they function better in damp and especially misty environments. The damp, misty environment may be due to the use of water as a cooling for the processing head during the processing of concrete objects.

In a preferred embodiment of the method, the holder includes a head exchanger and the robotic arm exchanges the active processing head or measuring head in the holder against a processing head or measuring head from a repository comprising one or more processing heads and/or measuring heads, after which the latter processing head / measuring head the new active processing head / measuring head is. Usually, the operation and/or measurement of the object includes several steps. In a non-limiting example, the operation comprises milling the top layer of material and then smooth polishing of the milled surface. In another non-limiting example, the object is first measured by the robotic arm with active measuring head and then edited in one or more steps by the active robotic arm. In case the operation and/or measurement of the object includes multiple such steps, it is advantageous that the device switches automatically from the processing head / measuring head; in this way human intervention is minimized.

In a preferred embodiment of the method, the positional information is measured at least in part by means of a measurement module comprised by an active measuring head. This has the advantage of minimizing human intervention, especially when measurement is followed immediately by processing the object. In a further preferred embodiment, the measurement module comprises a laser distance meter and in an even more preferred embodiment, the measurement module comprises a 3D scanner comprising a laser distance meter. In a further or alternative preferred embodiment, the measurement module includes one or more acoustic sensors, mechanical sensors or sensors of any other type suitable for measuring distances and/or positions.

In a preferred embodiment of the method, the object is stationary during operation and the rotational and translational degrees of freedom of the robotic arm suffice for performing the intended operation and/or measurement of the object through the active processing head and/or measuring head. The stationary arrangement of the object is beneficial for the safety of the residents. Often it's about big and heavy objects. In addition, the risk of damage to the concrete object is greater when its position and/or orientation is changed one or more times during the operation. Consequently, it is advantageous to construct the concrete object stationary. We distinguish the rotational and translational degrees of freedom of the robotic arm. A rotational freedom of the robotic arm is preferably realized by a module which is journaled on another module, provided with an actuator, preferably a servo motor. Said actuator may be controlled from the computer such that for each degree of rotation, the rotation angle of the first module relative to the second can be adjusted and changed from the computer. A translational degree of freedom of the robotic arm is preferably realized by a module which is slidable by or along another module, provided with an actuator, preferably an electronically controlled pneumatic piston. Said actuator may be controlled from the computer such that for each translation degree of freedom of the extended length of the first module relative to the second can be adjusted and changed from the computer. Rotational and/or translational degrees of freedom can be combined. The robotic arm then consists of an attachment module and a series of one or more moving modules. The first free module of the series is either stored on the attachment module as described above, or it is slidably held by or along the attachment module again as described above. Each of the following free modules is then either stored on either slidable by or along the previous free module from the series. The holder for processing heads and/or measuring heads is preferably comprised of the last module of the series, because it has the highest degree of freedom at its disposal. Preferably, the robotic arm has multiple degrees of freedom and no translational degree of freedom . For the operation of a stationary object by means of a robotic arm, it is either that the robotic arm itself is moved, or that the robotic arm is also stationary. In the second case, the rotational and translational degrees of freedom of the robotic arm should of course be sufficient for the operation of the object.

In a preferred embodiment of the method, the object is stationary disposed during the operation, the robotic arm is hangingly mounted on a travelling crane and the rotation and translational degrees of freedom of the travelling crane and robotic arm combination to perform the intended operation and/or measurement of the object through the active processing head and/or measuring head. The hangingly mounting of the robotic arm on the travelling crane has the advantage that the travelling crane provides two additional translational degrees of freedom . As a result, many larger objects can be edited than would be the case with the stationary robotic arm alone. Typically, these translational degrees of freedom describe the depth and width of the workplace. Often, a stationary robotic arm also has insufficient degrees of freedom to manipulate large objects, with typical dimensions greater than 2m. One possible solution is that the object is being processed in different phases, each phase being followed by a displacement of the object. However, this is dangerous when it comes to heavy concrete objects. In addition, there is a risk of damage to the object as a result of any displacement. This can be avoided by mounting the robotic arm on a travelling crane.

In a preferred embodiment of the method, the whole of the active processing head and the processing heads in the repository comprise at least one milling head and a polishing head. This is advantageous, as milling and polishing are among the most commonly applied to stone materials. In a further preferred embodiment, each object is first milled and then polished. In a further preferred embodiment, it is then automatically exchanged between a milling head and a polishing head. Preferably, the milling head is a steel disk, the curved side face of which is tipped and further comprises diamond particles. Multiple milling heads, with ever-increasing toothing, can be used for ever-increasing processing of the object's surface, always by pressing the curved side surface of the milling head against the object while the milling head rotates about the coordinate of the disc. Preferably, a polishing head is a circular piece of abrasive paper which abrases the surface in a rotating motion. Polishing heads of ever finer grain can be used for ever-better processing of the surface of the object. Additionally or in addition, use is made of another type of polishing head, which preferably comprises alcantara patch disc. In further preference, they are used in combination with one or more polishing pastes which allow to abrade the surface on the one hand and, on the other hand, shine.

In a preferred embodiment of the method, the object concerns a concrete staircase or granulator trailing element, and the method comprises removing a layer of 1 to 20 mm thickness of one or more surfaces through the milling head, which during this operation is the active processing head. In further preference, a layer of 3 mm to 5 mm thickness is milled away, and even more preferably a layer of 3.75 mm to 4.25 mm thickness is milled away. The release of a layer of suitable thickness of a concrete object with granulates, for example of a concrete staircase, has the advantage that the cross-section of the granulates is visible. This has an aesthetic effect, especially if the color of the cross-sectional diameter differs from the color of the matrix. The appropriate thickness of the layer to be milled dependent on the average diameter of the granules. Preferably the thickness of the layer to be milled is chosen so that the first layer of granulates is cut more or less centrally. For granulates with an average diameter of 8 mm, preferably a layer of thickness is milled at least 3 mm and maximum 5 mm at the surface. In further preference, a layer of thickness is minimally 3.75 mm and milled at most 4.25 mm.

In a preferred embodiment of the method, the object concerns a concrete stairs element having granulates and the method comprises polishing one or more surfaces by means of the polishing head which during the operation is the active processing head. Preferably, this polishing step is applied to a cured cast concrete object or to a milled concrete object. In further preference, the concrete object is a concrete staircase. The advantage of polishing is that the surfaces can be made much smoother. This facilitates the maintenance of the concrete staircase; in particular, it simplifies the cleaning of the stairway surface.

In a second aspect, the present invention discloses an processing device for processing a three-dimensional concrete object, for example for processing a concrete stairs element having granulates comprising a robotic arm and a holder for a processing head and/or measuring head provided with the robotic arm with characterized in that at least one measurement module is provided suitable for measuring positional information with respect to one or more reference points located on the object to be processed. This has the advantage that the device is suitable for charging the actual shape and dimensions of the object, which may deviate from the theoretical shape and dimensions. In addition, the device is also suitable for determining the position and orientation of the object to be processed.

In a preferred embodiment of the processing device, a measurement module is provided on the robotic arm. This has the advantage that the device is suitable for fully measuring the positional information so that human intervention can be minimized. In further preference, the measurement module is comprised of the latter from the series of free modules of the robotic arm, because it has the highest degree of freedom at its disposal.

In a preferred embodiment of the processing device, there is a measurement module comprised of an exchangeable measuring head. This has the advantage that the device is suitable for fully measuring the positional information so that human intervention can be minimized. In this case, the positional information can be measured at least partially by means of an exchangeable measuring head in the holder at the robotic arm. In this way, the measuring head can be accommodated in the repository during the operation of the object. This is advantageous since the optional fragile measuring head is then not exposed to flying concrete particles, alkaline concrete mud and/or concrete dust and water.

In a preferred embodiment of the processing device, a measurement module is provided which is separate from the robotic arm. The use of a stand-alone read-in module has the advantage that the robotic arm can be optimally utilized for processing objects, which are read in advance with a separate read-in module, apart from the robotic arm.

In a preferred embodiment of the processing device, at least one measurement module comprises a laser distance meter, which is based on the principle of triangulation measurement and/or travel time measurement. Preferably at least one measurement module comprises a laser distance meter, based on the principle of triangle measurement. The advantage of this type of laser distance meter is the combination of a potentially very fast measurement and a potentially very high accuracy; some devices are capable of measuring more than 1000 reference points per second, with an accuracy higher than 1 mm. This, for objects with maximum dimensions not greater than 10 meters. More preferably, at least one measurement module comprises a 3D scanner, comprising the laser distance meter. In a further preferred embodiment of the processing device, each measurement module comprises a laser distance meter and in an even more preferred embodiment, each measurement module comprises a 3D scanner, comprising a laser distance meter.

In a further or alternative preferred embodiment of the processing device, at least one measurement module comprises one or more acoustic sensors, mechanical sensors, and/or sensors of any other type, suitable for measuring distances and/or positions. Among other (waterproof) mechanical sensors have the advantage over laser distance meters that they function better in damp and especially misty/foggy environments. Water jets are often used as cooling for the processing head, during the processing of concrete objects.

In a preferred embodiment of the processing device, the processing device moreover comprises a computer, suitable for controlling the robotic arm and for exchanging positional information with at least one measurement module. In a further preferred embodiment, that same computer is suitable for compiling the true model for the object from the measured positional information and/or the theoretical plan. The fact that the device is suitable for fully automated data exchange and processing has the advantage that human intervention can be avoided as much as possible when using the device.

In a preferred embodiment of the processing device, the robotic arm is hangingly mounted on a travelling crane and the computer is suitable for driving this travelling crane. The hangingly mounting of the robotic arm to the travelling crane has as an effect that the travelling crane provides two additional translational degrees of freedom. The advantage is that the processing device is suitable for processing much larger objects than would be the case with the aid of a stationary robotic arm alone. Typically, these translational degrees of freedom describe the depth direction and width direction of the work space. Another advantage is that an object can be measured with a module that is separate from the robotic arm, while the robotic arm is processing a second object, at another location in the work space. After processing of the second object, the robotic arm can then be brought into the vicinity of the first object in a simple manner, where it can immediately begin with the operation.

In a preferred embodiment of the method, the device comprises a repository, comprising one or more exchangeable processing heads and/or exchangeable measuring heads and the holder includes a head exchanger suitable for interchangeably holding a processing head/measuring head, in held state called the active processing head/measuring head. Usually, the processing device will be applied for the method described above and comprises multiple processing steps and/or measuring steps. In a non-limiting example, the processing comprises the removal by milling of a top layer of material and the subsequent smooth polishing of the milled surface. In another non-limiting example, the object is first measured by the robotic arm with active measuring head and then processed in one or more steps by the robotic arm with active processing head. In case the processing and/or measurement of the object comprises multiple such steps, it is advantageous that the device is suitable for automatically changing the processing head/measuring head. In this way, human intervention is reduced to a minimum.

In a preferred embodiment of the processing device, the whole of the active processing head and the processing heads in the repository comprise at least a milling head and a polishing head. This is advantageous, as milling and polishing belong to the operations which are most commonly applied to stone materials. In a further preferred embodiment, each object is first milled by means of the milling head and then polished by means of the polishing head. The processing device is then suitable for the automatic switching between the milling head and the polishing head. Preferably, the milling head is a steel disk, of which the curved side surface is serrated and more preferably comprises diamond particles. Preferably a polishing head is a circular piece of abrasive paper, which is suitable for abrasion of the surface by means of a rotational movement around the axis of the circle. In another preferred embodiment, the polishing head is an alcantara cloth rings.

Preferably, the processing device described above is suitable for carrying out the method as described above and/or in any of claims 1 up to and including 16.

DETAILED DESCRIPTION OF THE FIGURES

The invention will now be further elucidated with reference to the following example and accompanying figures, without being limited thereto.

Figure 1 shows a two-dimensional front view of an embodiment of the processing device, with a robotic arm **5,** hangingly mounted to a travelling crane **1**. Preferably, the range of the travelling crane **1** covers the entire work space, or at least a part thereof. For example, the rolling bridge **1** covers a rectangular column of width of about 10 m and depth of about 40 m. For this purpose, the travelling crane **1** comprises two stationary profiles **2**, a depth direction configurable profile **3** and a width direction configurable element **4**. The two stationary profiles **2** are directed according to the rectangle's depth direction; they are supported by pillars and/or by the side wall of the work space and are fixed at a constant height between 2 m and 12 m above the surface of the work space, preferably between 2 m and 6 m, on both sides of the rectangle. These stationary profiles **2** are suitable for slidably supporting and/or carrying the depth direction configurable profiles **3**. The depth direction configurable profile **3** is oriented according to the width of the rectangle; it is slidably supported and/or carried at both end parts by the stationary profiles **2,** such that the position thereof can be slidably adjusted in the depth direction, along the stationary profiles **2**. The depth direction configurable profile **3** is suitable for slidably supporting and/or carrying the width direction configurable element **4**. The width direction configurable element **4** is slidably supported and/or carried by the depth direction configurable profile **3**, such that its position can be slidably adjusted in the width direction, along the depth direction configurable profile **3**. In this manner, the travelling crane provides two translational degrees of freedom, one in the width direction and one in the depth direction of the rectangle. By a well-chosen setting of both, the position of the width direction configurable element **4** can be realized anywhere the rectangle. The robotic arm **5** is preferably hangingly mounted to the width direction configurable element **4**. By a well-chosen setting of both translational degrees of freedom, the position of the attachment module of the robotic arm **5** can be realized anywhere in the rectangle . Preferably, the travelling crane is computer-controlled so that the position of the width direction configurable element **4** along the depth direction configurable profile**3,** as well as the position of the depth direction configurable profile **3** along the stationary profiles **2** can be automatically adjusted from the computer.

Figure 2 shows a three-dimensional perspective of an embodiment of the robotic arm **5** with milling head **7**. The robotic arm **5** has one or more rotational degrees of freedom. Preferably, the robotic arm **5** has two or more rotational degrees of freedom. The robotic arm **5**, as shown in Figure 2, has 6 rotational degrees of freedom, each realized by a pivot point **6**. In a preferred embodiment of the present method, first the position of the attachment module of the robotic arm **5** is set near the object to be processed, using the translational degrees of freedom of the travelling crane **1**. Then, during the processing of the object, only the angles corresponding to the rotational degrees of freedomare changed from the computer. The exchangeable processing head, in this case a milling head **7**, is held exchangeably by a holder having a head exchanger **8**. Furthermore, the robotic arm **5** comprises water spray nozzles **9,** suitable for directing a water jet **11** to the processing head and/or the processed surface, during processing of the object. This, for the purpose of cooling the processing head and/or the processed surface. Water is supplied from a water pipe **10**.

Figure 3a shows a three-dimensional perspective of an embodiment of the method, during the polishing of a concrete stairs element having granulates **12**. For polishing surfaces, a modified polishing head **13** is used. During polishing, the surface and/or the processing head is moistened by water jets **11**. The water is supplied via a water pipe **10**. In a preferred embodiment of the method, the concrete stairs element having granulates **12** is first milled and then polished. The milling is thereby suitable for removing a relatively thick layer of material, with a thickness of a few millimeters. In this way, a cross-section of the granulate becomes visible on the surface. Polishing is rather suitable to make the milled surface smoother and possibly to make it shine. This is beneficial for the maintenance of the stairway surface. In a preferred embodiment of the method, only the rotational degrees of freedom, corresponding to the pivot points **6,** are varied during polishing of the surface.

Figure 3b shows a three-dimensional perspective of an embodiment of the method, during the milling of a concrete stairs element having granulates **12**. During milling, the surface and/or the processing head is moistened via water jets **11** from the water spray nozzles **9**. The water is supplied via a water pipe **10**. The milling is thereby suitable for removing a relatively thick layer of material, with a thickness of a few millimeters. In this way, a cross-section of the granulate becomes visible on the surface. In a preferred embodiment of the method, only the rotational degrees of freedom of rotation, corresponding to the pivot points **6,** are varied during milling of the surface.

The numbered elements in the figures are:

1. travelling crane
2. stationary profiles
3. depth direction configurable profile
4. width direction configurable element
5. robotic arm
6. Pivot points of robotic arm
7. milling head
8. holder having ahead exchanger
9. water spray nozzles
10. water pipe
11. water jet
12. concrete stairs element having granulates
13. polishing head

REVENDICATIONS

LU100513

1. Une méthode pour le traitement d'un objet tridimensionnel en béton, ladite méthode comprenant la phase du traitement de l'objet au moyen d'une tête de traitement active, ladite tête de traitement étant prévue à cet effet dans un support sur un bras robotique, lequel objet en béton, avant ledit traitement, étant coulé dans une forme, dans lequel ladite forme est déterminée à base d'un modèle théorique pour l'objet, et dans lequel le traitement comprend le polissage d'une ou plusieurs surfaces et/ou le fraisage d'une couche de 1 à 20 mm d'épaisseur d'une ou de plusieurs surfaces de l'objet, **caractérisée en ce que** ledit traitement est réalisé à base d'un vrai modèle, ledit vrai modèle étant dessiné à base dudit modèle théorique, combiné avec d'information positionnelle mesurée par rapport à un ou plusieurs points de référence situés sur l'objet.
2. La méthode suivant revendications 1, **caractérisée en ce que** ladite information positionnelle est au moins partiellement mesurée au moyen d'un module de mesure, lequel module de mesure étant, à cet effet, prévu dudit bras robotique.
3. La méthode suivant une des revendications 1 à 2, **caractérisée en ce que** ladite information positionnelle est au moins partiellement mesurée au moyen d'un module de mesure, lequel module de mesure étant séparé dudit bras robotique.
4. La méthode suivant une des revendications, **caractérisée en ce que** ledit bras robotique est contrôlé par ordinateur, dans lequel ledit ordinateur échange des informations positionnelles avec au moins un module de mesure.
5. La méthode suivant une des revendications, **caractérisée en ce que** ledit bras robotique est contrôlé par ordinateur, dans lequel ladite information positionnelle est introduite dans et/ou adaptée dans ledit ordinateur au moins partiellement manuellement.
6. La méthode suivant une des revendications précédentes, **caractérisée en ce que** au moins un module de mesure comprend un appareil de mesure des distances laser, lequel appareil de mesure des distances laser est basé sur le principe de triangulation et/ou de mesure de temps de déplacement.
7. La méthode suivant une des revendications précédentes, **caractérisée en ce que** ledit support comprend un échangeur de têtes, et que ledit bras robotique échange la tête de traitement active ou la tête de mesure active, dans ledit support, contre une tête de traitement ou une tête de mesure depuis un dépôt comprenant une ou plusieurs têtes de traitement et/ou têtes de mesure, après quoi ladite tête de traitement ou ladite tête de mesure est la nouvelle tête de traitement/mesure active.
8. La méthode suivant une des revendications précédentes, **caractérisée en ce que** ladite information positionnelle est au moins partiellement mesurée au moyen d'un

module de mesure, lequel module de mesure est compris dans une tête de mesure active. LU100513

9. La méthode suivant une des revendications précédentes, **caractérisée en ce que** pendant ledit traitement, ledit objet est arrangé de manière stationnaire, dans lequel les degrés de liberté de rotation et de translation dudit bras robotique suffissent pour la réalisation du traitement prévu et/ou de la mesure de l'objet au moyen de la tête de traitement et/ou la tête de mesure active.
10. La méthode suivant une des revendications précédentes, **caractérisée en ce que** pendant ledit traitement, ledit objet est arrangé de manière stationnaire, dans lequel ledit bras robotique est monté par suspension à un pont roulant, et que les degrés de liberté de rotation et translation de la combinaison de ledit pont roulant et dudit bras robotique suffissent pour la réalisation du traitement prévu et/ou de la mesure de l'objet au moyen de la tête de traitement et/ou la tête de mesure active.
11. La méthode suivant une des revendications précédentes, **caractérisée en ce que** l'ensemble des têtes de traitement et des têtes de mesure dans le dépôt comprennent au moins une tête de broyage et une tête de polissage.
12. La méthode suivant une des revendications précédentes, **caractérisée en ce que** l'objet est un escalier ou des éléments d'escalier en béton ayant des granulés, et que ladite méthode comprend la phase du broyage d'une couche d'une épaisseur de 1 à 20 mm d'une ou plusieurs surfaces, au moyen de ladite tête de broyage, laquelle tête de broyage pendant le traitement est une tête de traitement active.
13. La méthode suivant une des revendications précédentes, **caractérisée en ce que** l'objet est un escalier en béton ayant des granulés, et que ladite méthode comprend la phase de polissage d'une ou plusieurs surfaces, au moyen de ladite tête de polissage, laquelle tête de polissage pendant le traitement est une tête de traitement active.
14. Un dispositif de traitement pour le traitement d'un objet tridimensionnelle en béton, par exemple pour le traitement d'un escalier en béton ayant des granulés, ledit dispositif comprenant un bras robotique, et un support pour une tête de traitement et/ou une tête de mesure, lequel support est prévu sur ledit bras robotique, dans lequel au moins un module de mesure est prévu, approprié pour la mesure d'information positionnelle par rapport à un ou plusieurs points de référence, lesquels points de référence se situent sur l'objet à traiter, et **caractérisée en ce qu'**un module de mesure est prévu sur ledit bras robotique.
15. Le dispositif de traitement suivant revendication 14, **caractérisée en ce qu'**un module de mesure est compris dans une tête de mesure échangeable.

16. Le dispositif de traitement suivant une des revendications 14 à 15, **caractérisée en ce qu'**un module de mesure est prévu, ledit module de mesure est séparé dudit bras robotique. LU100513
17. Le dispositif de traitement suivant une des revendications précédentes, **caractérisée en ce qu'**au moins un module de mesure comprend un appareil de mesure des distances laser, lequel appareil de mesure des distances laser est basé sur le principe de triangulation et/ou de mesure de temps de déplacement.
18. Le dispositif de traitement suivant une des revendications précédentes, **caractérisée en ce que** le dispositif de traitement comprend en plus un ordinateur, approprié pour contrôler le bras robotique, et pour échanger l'information positionnelle avec au moins un module de mesure.
19. Le dispositif de traitement suivant une des revendications précédentes, **caractérisée en ce que** l'bras robotique est monté par suspension à un pont roulant, et que l'ordinateur est approprié à contrôler ledit pont roulant.
20. Le dispositif de traitement suivant une des revendications précédentes, **caractérisée en ce que** le dispositif comprend un dépôt comprenant une ou plusieurs têtes de traitement échangeables et/ou têtes de mesure échangeables, et que le support comprend un échangeur de têtes, approprié à soutenir de manière échangeable une tête de traitement/mesure, laquelle tête de traitement/mesure dans une configuration maintenue est appelée la tête de traitement/mesure active.
21. Le dispositif de traitement suivant une des revendications précédentes, **caractérisée en ce que** l'ensemble des têtes de traitement et des têtes de mesure dans le dépôt comprennent au moins une tête de broyage et une tête de polissage.
22. Le dispositif de traitement suivant une des revendications précédentes, **caractérisée en ce que** ledit dispositif est approprié à réaliser la méthode suivant une des revendications 1 à 13.

FIGUREN

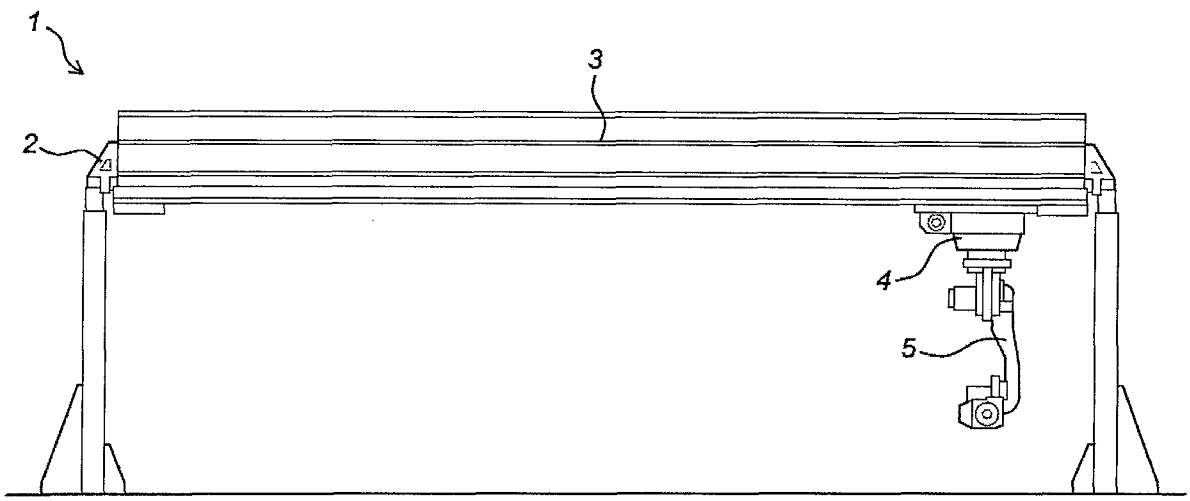

Fig. 1

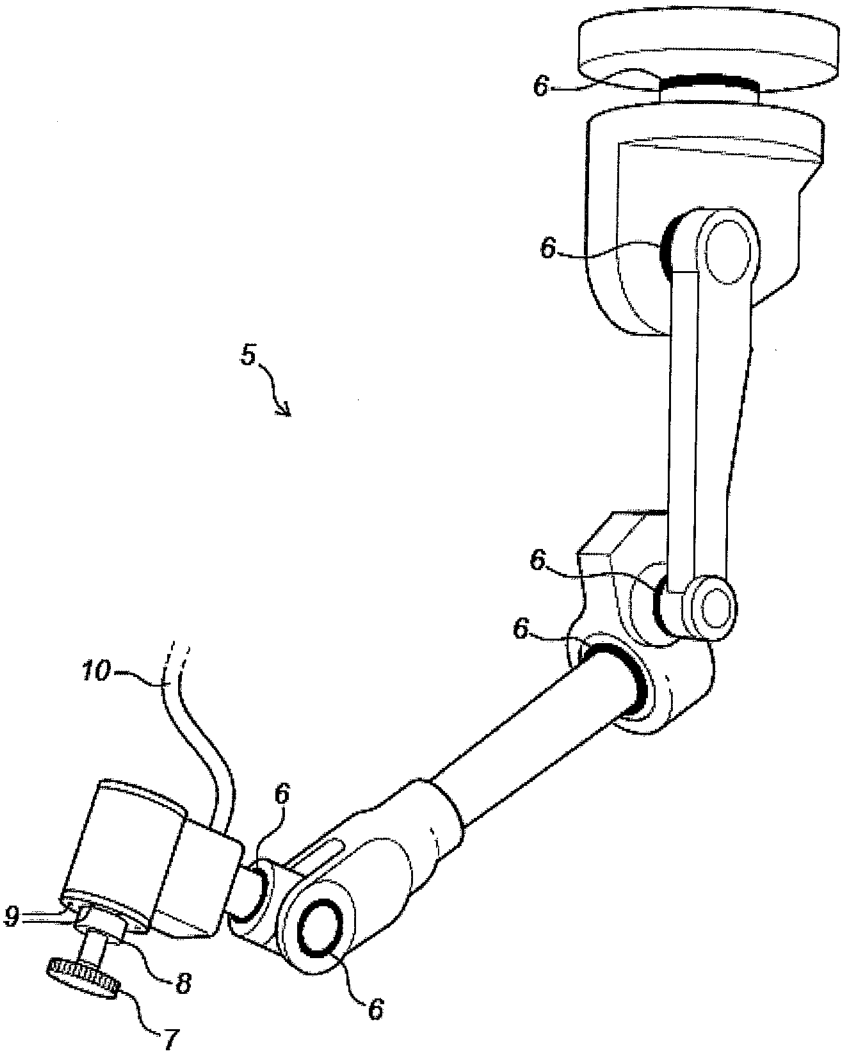

Fig. 2

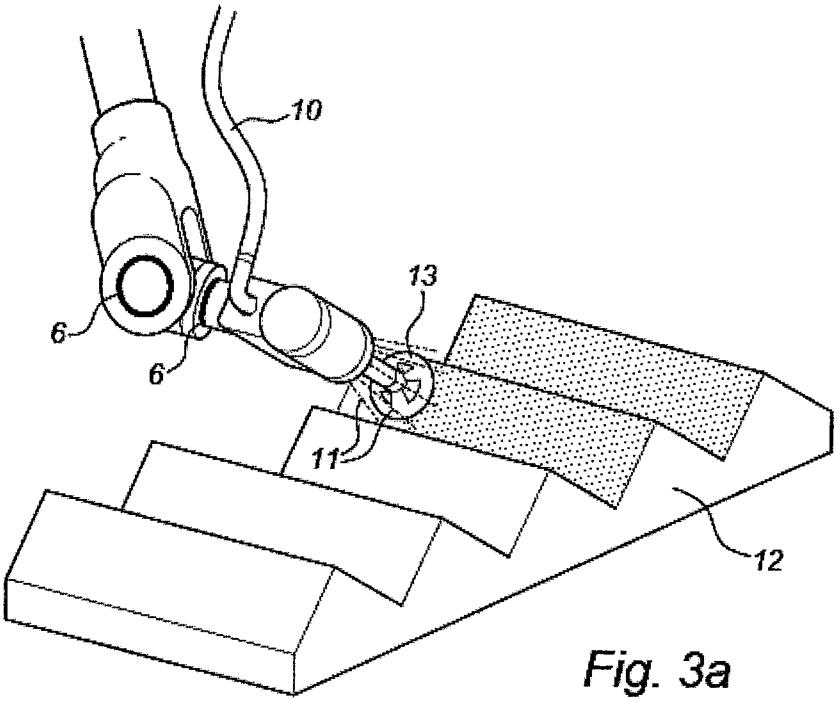

Fig. 3a

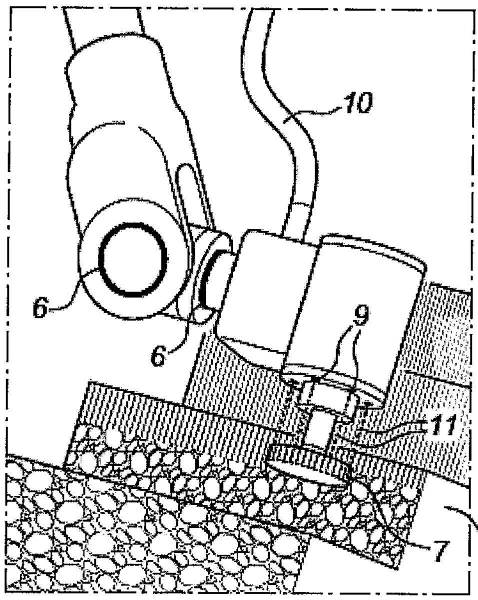

Fig. 3b

METHOD AND DEVICE FOR PROCESSING A THREE-DIMENSIONAL, CONCRETE OBJECT

ABSTRACT

In a first aspect, the present invention describes a method for processing a three-dimensional concrete object, for example for processing a concrete stairs element having granulates, comprising processing the object by means of an active processing head for that purpose provided in a holder on a robotic arm, characterized in that the processing is done by means of a true model, made up based on measured, positional information with respect to one or more reference points located on the object. In a second aspect, the invention relates to a processing device for processing a three-dimensional concrete object, comprising a robotic arm and a holder for a processing head and/or measuring head, provided at the robotic arm, characterized in that at least one measuring module is provided, suitable for measuring positional information with respect to one or more reference points located on the object to be processed.

LE GOUVERNEMENT
DU GRAND-DUCHÉ DE LUXEMBOURG
Ministère de l'Économie

SEARCH REPORT

in accordance with Article 35.1 a)
of the Luxembourg law on patents
dated 20 July 1992

National Application Number

LO 1808
LU 100513

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	DE 10 2007 052056 A1 (PRINZING GEORG GMBH CO KG [DE]) 13 November 2008 (2008-11-13)	1-4,6-9, 11,12, 14,17, 19-22, 24-26	INV. B28B11/12 G01B21/04 G01N21/88 G06T7/00 B28D1/00 B28D1/30 B28D7/00
Y	* paragraph [0040] - paragraph [0049]; claims 1-5,16,26; figures * * paragraph [0020] - paragraph [0028] * -----	5,10-13, 15,16,18	
X	CN 204 673 769 U (SHANGHAI YUSHANHONG MACHINERY MFG CO LTD; ZHANG WEI) 30 September 2015 (2015-09-30) * abstract; figures * -----	1,3,6-9, 11,17, 20-23,26	
Y	DE 10 2010 054973 A1 (ZEISS IND MESSTECHNIK GMBH [DE]) 14 June 2012 (2012-06-14) * paragraph [0111] - paragraph [0125]; figures * -----	5,10-13, 18	
Y	FR 2 694 720 A1 (THIBAUT SA [FR]) 18 February 1994 (1994-02-18) * page 2, line 1 - page 3, line 7 * * page 6, line 9 - page 8, line 25 * -----	15,16	TECHNICAL FIELDS SEARCHED (IPC) B28B G01B G01N G06T B28D B24B

The present search report has been drawn up for all claims

	Date of completion of the search	Examiner
	29 May 2018	Orij, Jack

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

1

EPO FORM 1503 03.82 (P04C36)

ANNEX TO THE SEARCH REPORT ON LUXEMBOURG PATENT APPLICATION NO.

LO 1808
LU 100513

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

29-05-2018

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
DE 102007052056 A1	13-11-2008	DE 102007052056 A1 DE 202007019147 U1 EP 2527118 A1	13-11-2008 16-12-2010 28-11-2012
CN 204673769 U	30-09-2015	NONE	
DE 102010054973 A1	14-06-2012	NONE	
FR 2694720 A1	18-02-1994	NONE	

EPO FORM P0459

LE GOUVERNEMENT
DU GRAND-DUCHÉ DE LUXEMBOURG
Ministère de l'Économie

WRITTEN OPINION

File No.	Filing date *(day/month/year)*	Priority date *(day/month/year)*	Application No.
LO1808	07.11.2017	07.11.2016	LU100513

International Patent Classification (IPC)
INV. B28B11/12 G01B21/04 G01N21/88 G06T7/00 B28D1/00 B28D1/30 B28D7/00

Applicant
Declercq Stortbeton nv

This report contains indications relating to the following items:

- ☒ Box No. I — Basis of the opinion
- ☐ Box No. II — Priority
- ☐ Box No. III — Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
- ☐ Box No. IV — Lack of unity of invention
- ☒ Box No. V — Reasoned statement with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
- ☐ Box No. VI — Certain documents cited
- ☒ Box No. VII — Certain defects in the application
- ☒ Box No. VIII — Certain observations on the application

Examiner
Orij, Jack

WRITTEN OPINION

Box No. I Basis of the opinion

1. This opinion has been established on the basis of the latest set of claims filed before the start of the search.
2. With regard to any **nucleotide and/or amino acid sequence** disclosed in the application and necessary to the claimed invention, this opinion has been established on the basis of:

   a. type of material:

   ☐ a sequence listing

   ☐ table(s) related to the sequence listing

   b. format of material:

   ☐ on paper

   ☐ in electronic form

   c. time of filing/furnishing:

   ☐ contained in the application as filed.

   ☐ filed together with the application in electronic form.

   ☐ furnished subsequently.

3. ☐ In addition, in the case that more than one version or copy of a sequence listing and/or table relating thereto has been filed or furnished, the required statements that the information in the subsequent or additional copies is identical to that in the application as filed or does not go beyond the application as filed, as appropriate, were furnished.
4. Additional comments:

Box No. V Reasoned statement with regard to novelty, inventive step and industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty	Yes:	Claims	5, 10, 13, 15, 16, 18
	No:	Claims	1-4, 6-9, 11, 12, 14, 17, 19-26
Inventive step	Yes:	Claims	
	No:	Claims	1-26
Industrial applicability	Yes:	Claims	1-26
	No:	Claims	

2. Citations and explanations

   see separate sheet

WRITTEN OPINION

Box No. VII Certain defects in the application

The following defects in the form or contents of the application have been noted:

see separate sheet

Box No. VIII Certain observations on the application

see separate sheet

Re Item V

Reasoned statement with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1 Reference is made to the following documents:

D1 DE 10 2007 052056 A1 (PRINZING GEORG GMBH CO KG [DE]) 13 november 2008 (2008-11-13)

D2 CN 204 673 769 U (SHANGHAI YUSHANHONG MACHINERY MFG CO LTD; ZHANG WEI) 30 september 2015 (2015-09-30)

D3 DE 10 2010 054973 A1 (ZEISS IND MESSTECHNIK GMBH [DE]) 14 juni 2012 (2012-06-14)

D4 FR 2 694 720 A1 (THIBAUT SA [FR]) 18 februari 1994 (1994-02-18)

2 The present application does not meet the criteria of patentability, because the subject-matter of **independent claims 1 and 17** is not new.

2.1 The document D1 discloses (the references in parentheses applying to this document) a method for processing a three-dimensional, concrete object, *for example for processing a concrete staircase having granulates [see Item VIII, §1]*, said method comprising the step of processing the object by means of an active processing head (5), which processing head is thereto provided in a holder on a robotic arm (22), wherein said processing is executed on the basis of a true model, which true model is drawn up on the basis of measured, positional information relating to one or more reference points located on the object (paragraph [0040] - paragraph [0049]; claims 1-5,16,26; figures; paragraph [0020] - paragraph [0028]).

Document D2 equally disclose the features of claim 1, see the corresponding passages cited in the search report.

The subject-matter of **claim 1** is therefore deprived from novelty.

2.2 The document D1 discloses (the references in parentheses applying to this document) a processing device for processing a three-dimensional, concrete object (1), *for example for processing a concrete staircase having granulates [see Item VIII, §1]*, said device comprising a robotic arm (22), and a holder for a processing head (5) and/or measuring head, which holder is provided on said robotic arm (22), wherein at least one measuring module (27) is provided, suitable for measuring positional information relating to one or more reference points, which reference points are located on the object to be processed (paragraph [0040] - paragraph [0049]; claims 1-5,16,26; figures; paragraph [0020] - paragraph [0028]).

The subject-matter of **claim 17** is therefore deprived from novelty.

3 Dependent **claims 2-16 and 18-26** do not contain any features which, in combination with the features of any claim to which they refer, meet the requirements of novelty, see documents D1-D4 and the corresponding passages cited in the search report.

3.1 Document D1 discloses a method for measuring the cast concrete element and to determine its position. It furthermore discloses a robotic arm and a tool exchanger.

3.2 Document D3 discloses a measurement system and computer program including instructions for measuring the geometry of an object. The system comprises a gantry construction holding the measurement head.

3.3 Document D4 discloses a numerical controlled machine for working the surface of a concrete staircase. The concrete staircase is position at a reference point before the working operations can start. The use of a reference point or creating a numerical model is merely one of several straightforward possibilities from which the skilled person would select, in accordance with circumstances, without the exercise of inventive skill, in order to be able to work the surface of a concrete object.

Re Item VII

Certain defects in the application

1 The relevant background art disclosed in the documents D1-D4 is not mentioned in the description, nor are these documents identified therein.

2 The features of the claims are not provided with reference signs placed in parentheses.

Re Item VIII

Certain observations on the application

1 The expression "for example" in claims **1 and 17** has no limiting effect on the scope of said claims. That is to say, the features following such an expression are to be regarded as entirely optional.

2 The following statement in the description on page 2, lines 5-6 and on page 3, lines 21-22 "in particular, the operation is done on the basis of a true model" implies that the subject-matter for which protection is sought may be different to that defined by the claims, thereby resulting in lack of clarity when used to interpret them.