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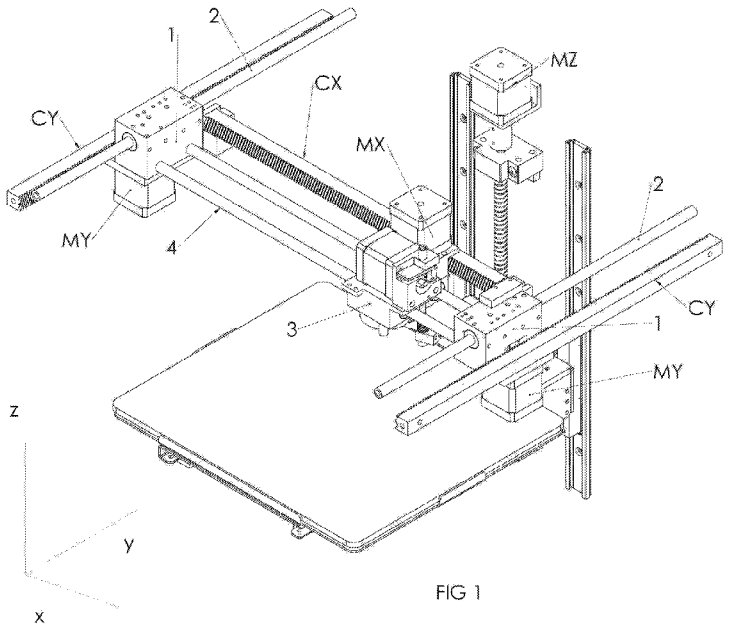

FIG 1

(57) Abstract: A mechatronic movement system for three- dimensional printing means of a rapid-prototyping machine, such as a 3D printer, of the type provided with at least one microprocessor electronic management board, in which the movement of the printing means of the 3D printer along the axes X and Y of the horizontal plane is obtained exclusively with geared kinematic chains.

WO 2016/147111 A1

MECHATRONIC MOVEMENT SYSTEM FOR THREE-DIMENSIONAL PRINTER USING HELICAL RACKS AND PINIONS

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The present invention relates to the sector of rapid-prototyping machines, commonly referred to by the name of "3D printers".

3D printing can be considered as the natural evolution of 2D printing and presents the major advantage of being able to provide a real reproduction of a 3D model that has previously been created with one of the current three-dimensional modelling programs. With this technique, three-dimensional objects are created via deposition of successive layers of material.

Basically, it may be said that a 3D printer uses a file of a three-dimensional model of an object and "breaks it down" to define a series of portions of the object in cross-sectional view. In other words, these portions are "slices" of the object to be created that are printed on top of one another to create the 3D object layer after layer.

There exist different 3D-printing technologies, and their main differences regard the way in which the layers are printed. Some methods use materials that fuse or are softened to produce the layers, for example, selective laser sintering (SLS) and fused deposition modelling (FDM), whereas others deposit liquid materials that are hardened using various technologies. In the case of lamination systems, there are thin layers that are cut according to the shape and joined together.

Any 3D-printing technology is characterized by advantages and disadvantages, the main factors taken into consideration being the speed, the cost of the printed prototype, the cost of the 3D printer, the choice of the materials, the colours available, etc.

Without wishing to dwell on the examination of the various 3D-printing technologies and methods, it should be noted that a problem common to all current 3D printers, regards the movement of the apparatuses that have to make the print.

Almost all currently known 3D printers use a cartesian movement governed by kinematic chains constituted by ordinary belts, pulleys, and belt-tensioners, moved by stepper motors.

Consequently, the resulting transmission ratio that derives therefrom may not be constant over time on account of the elasticity of the belts, which does not always guarantee the homogeneity of the movement and transmission of the motion along the kinematic chain. In a kinematic chain of a belt type, whether with cogged or non-cogged belts, the transmission ratio must always take into account a difference (referred to frequently as "DELTA") between the value of the force applied by the drive pulley and the value of the force to which the driven pulley is subjected, said difference between the aforesaid values being determined by the transmission of the motion through secondary components (pulleys, belt-tensioners, belts, etc.).

Belt transmission cannot be considered altogether precise as in the case of geared kinematic chains in so

far as over time possible sliding and/or structural yielding of the belt itself cannot be excluded, above all if the latter is made of rubber or materials subject to wear.

It may happen, for example that to an initial motion of the drive pulley there does not correspond instantaneously a consequent motion of the driven pulley, and this is due to the presence of the belt-tensioners, which may be elastic, and/or is due to the intrinsic elasticity of the belt that connects the two pulleys.

In a transmission ratio of a geared kinematic chain (e.g., rack and pinion, gears, ballscrews with spindles), the aforesaid difference (DELTA) almost goes to zero, the geared kinematic chain being far more precise and accurate and guaranteeing over time maintenance of the initial precision.

According to a peculiar characteristic of the invention, it is envisaged that the movement of the 3D printer is obtained exclusively with geared kinematic chains, which are constituted preferably by elements with helical teeth.

A second peculiar characteristic of the invention lies in the fact that the racks for movement of the printing means along at least one of the two axes of the horizontal plane X-Y do not move and are fixed with respect to the load-bearing structure (referred to in what follows also as "chassis") so that the member carrying more weight, i.e., the rack, remains stationary, and the pinion, which carries less weight, moves along it so as to obtain a drastic reduction of

the inertial masses to be displaced. Advantageously, it may be stated that moving a smaller inertial mass leads to considerable benefits, namely:

- less force to be applied to overcome the initial friction;

- possibility of increasing the speeds, with evident advantages in terms of shorter time for the production of a product according to the 3D-printing technique; and

- reduction of the torque necessary for the motor to overcome the initial friction, as well as of that for the acceleration/deceleration of the movement of the printing head, with consequent saving in terms of power and energy, as well as in terms of costs.

As has already been mentioned, in a preferred embodiment of the invention, the use of pinions and racks with helical teeth is envisaged. The helical solution enables considerable limitation of the problems regarding friction and noise that are typical of gears with straight teeth.

This solution consequently enables precision and accuracy of the geared transmission ratios, at the same time preventing or at least reducing considerably problems regarding friction, seizing, and noise during displacements.

The solution according to the present invention affords precision of positioning on the axes X-Y of the horizontal plane with consequent operative advantages on the yield and precision of the objects that are obtained with 3D printing, which cannot be achieved with a common movement governed by belts.

It is consequently evident that there derives a competitive advantage over currently known 3D printers.

As will emerge more clearly in what follows, using for example two racks with helical teeth and corresponding pinions on the axis Y and one helical rack and pinion on the axis X, it is possible to reduce drastically the backlash that could arise during operation. The gradual and smooth meshing typical of helical teeth makes it in fact possible to use less powerful motors, hence delivering less force. Moreover, the choice of fixing the racks directly on the chassis has a strategic importance for discharging the vibrations on the chassis itself and not on the working surface, where the three-dimensional piece is being printed.

A better understanding will be obtained from the ensuing detailed description of the invention with reference to annexed drawings, which illustrate a preferred embodiment thereof, purely by way of non-limiting example.

In the drawings:

Figure 1 is a front view that shows schematically the means for movement along the three axes X-Y-Z;

Figure 2 is an isometric view corresponding to the previous one, which also shows the platform on which the 3D object is created;

Figure 3 is a front view of a non-limiting example of a 3D printer installed in which are the movement means according to the invention; and

Figure 4 is a top plan view corresponding to the previous one.

According to the invention, movement along the axis X is managed by a rack and corresponding pinion (with at least one motor), whereas for the axis Y two racks are provided with respective pinions each fitted to a motor of its own. Said motors are connected in series to guarantee uniformity of motion. In addition, a precise calibration has been made of the phases of the motors, of the currents, of the voltages, as well as of the microsteppers.

The solution with dual rack-pinion and dual motor in series, now described with reference to the axis Y, has become necessary for counterbalancing the weight and for guaranteeing uniformity of the motion along the axis Y, given that the weight along the axis Y is far heavier than along the axis X.

In fact, weighing on the axis Y is the weight of the means for displacement along the axis X: motor Mx, rack Cx, carriage 3, guides 4, printing means of a known type, such as an extruder.

In this way, the maximum precision of positioning is guaranteed.

As shown in the figures, the two motors My are fixed to respective carriages 1 that slide on guides 2 arranged according to the axis Y and parallel to the racks Cy, whereas the corresponding pinions - fitted on the axes of said motors My - always mesh on said racks Cy.

The carriages Cy are rigidly connected together via two transverse guides 4 arranged according to the axis X, which are parallel to one another and perpendicular to the aforesaid guides 2. Running along

said transverse guides 4 is a third carriage 3, which is fixed with respect to a motor Mx, fitted on the axis of which is a pinion that always meshes with a corresponding rack Cx, which is also set perpendicular to said guides 2.

In the example of embodiment described, the above carriage 3 also supports the printing means 3D, which are constituted, for example, by an extruder.

As has already been mentioned, according to the invention, the guides 2 are arranged according to the axis Y and the guides 4 are arranged according to the axis X of the movement system described.

Given what has been said, the fact that the pinions of the motors always mesh with the respective racks and the fact that the teeth are of a helical type drastically reduces the play and noise of the kinematic movement chain, providing at the same time a high precision of movement and a precise control of the displacements imposed during production of the three-dimensional object.

As an alternative to the use of two motors My for movement of the carriages 1 along the guides 2 parallel to the axis Y, a single motor My may be provided fixed with respect to one of the carriages 1, and it may be envisaged to stiffen significantly the structural connection of said motor-driven carriage to the other carriage 1 for the axis Y, but this would necessarily lead to an undesirable increase in weight or costs resulting from the use of rigid materials, which are lighter but costly.

One of the possible alternatives that would enable

use of a single motor for each axis, in particular for the axis Y, could be to install a pinion also on the carriage 1 without motor My, envisaging a kinematic connection of said pinion to the pinion of the carriage 1 provided with motor My, via a geared kinematic chain, such as a system of bevel gears that co-operate with a transmission shaft, which connects them kinematically so that to a rotation of the pinion of one carriage 1 there corresponds an identical rotation of the pinion on the other carriage 1.

The movements of the various motors are managed in a known way by a microprocessor electronic board, which is able to process the data contained in a 3D graphic file.

The present invention has been described and illustrated in a preferred embodiment thereof, but it will be evident to any person skilled in the branch that functionally and/or technically equivalent modifications and or substitutions may be made thereto, without thereby departing from the sphere of protection of the present industrial patent right.

CLAIMS

1. A mechatronic movement system for three-dimensional printing means of a rapid-prototyping machine, such as for example a 3D printer, of the type equipped with at least one microprocessor electronic board, said movement system being characterized in that said printing means are mobile exclusively in the horizontal plane X-Y and in that moving of the printing means of the 3D printer along the axes X and Y of the horizontal plane is obtained exclusively via geared kinematic chains provided with pinions and racks (Cx, Cy) with helical teeth for reducing the play, vibrations, friction, and noise typical of gears with straight teeth; wherein the racks along the axis X or else those along the axis Y of the horizontal plane are fixed directly to the chassis of the system itself, whereas the resting surface of the three-dimensional object is mobile along the vertical axis Z via at least one ballscrew, driven by a motor (Mz).

2. The movement system according to the preceding claim, characterized in that the means for movement along the axis X comprise a rack (Cx) with a pinion always meshing thereon, fitted on a motor (Mx) controlled by the electronic management board; wherein said motor (Mx) is fixed with respect to a carriage (3) that runs on at least one purposely provided guide (4) set according to the axis X and parallel to the rack (Cx).

3. The movement system according to the preceding claim, characterized in that the means for movement along the axis Y comprise at least one rack

(Cy) always meshing with a respective pinion fitted on a corresponding motor (My) controlled by the electronic management board, wherein said motor (My) is fixed with respect to a carriage (1) that runs on at least one purposely provided guide (2) set according to the axis Y and parallel to the rack (Cy).

4. The movement system according to the preceding claim, characterized in that the means for movement along the axis Y comprise two motors (My), one for each carriage (2), wherein said motors are connected in series to guarantee uniformity of motion.

5. The movement system according to any one of Claims 2 onwards, characterized in that for each motor (Mx, My) a precise calibration of the phases, of the currents, of the voltages, as well as of the microsteppers, has been carried out.

6. The movement system according to Claim 4, characterized in that said two carriages (Cy) are rigidly connected together via two transverse guides (4) arranged according to the axis (X), which are parallel to one another and perpendicular to the aforesaid guides (2).

7. The movement system according to the preceding claim, characterized in that running on said transverse guides (4) is a third carriage (3) that is fixed with respect to a motor (Mx), fitted on the shaft of which is a pinion that always meshes with a corresponding rack (Cx), which is also set perpendicular to said guides (2).

8. The movement system according to Claim 5 or Claim 7, characterized in that said carriage (3) also

supports 3D printing means, which are constituted, for example, by an extruder.

9. The movement system according to the preceding claim, characterized in that each of said geared kinematic chains envisages the use of pinions and racks with helical teeth made of metal material.

10. The movement system according to Claim 4, characterized in that, as an alternative to the use of two motors (My) for movement of the carriages (1) along the guides (2) parallel to the axis Y, a single motor (My) is provided, which is fixed with respect to one of the carriages (1), as well as a rigid structural connection of said motor-driven carriage to the other carriage (1) running along the axis (Y).

11. The movement system according to Claim 4, characterized in that, as an alternative to the use of two motors (My) for movement of the carriages (1) along the guides (2) parallel to the axis Y, a single motor (My) is provided fixed with respect to one of the carriages (1), whereas on the other carriage (1) without motor, a pinion is provided kinematically connected to the pinion of the carriage (1) equipped with motor (My) via a geared kinematic chain, such as for example a system of bevel gears that co-operate with a transmission shaft that connects them in such a way that to a rotation of the pinion of one carriage (1) there will correspond an identical rotation of the pinion on the other carriage (1).

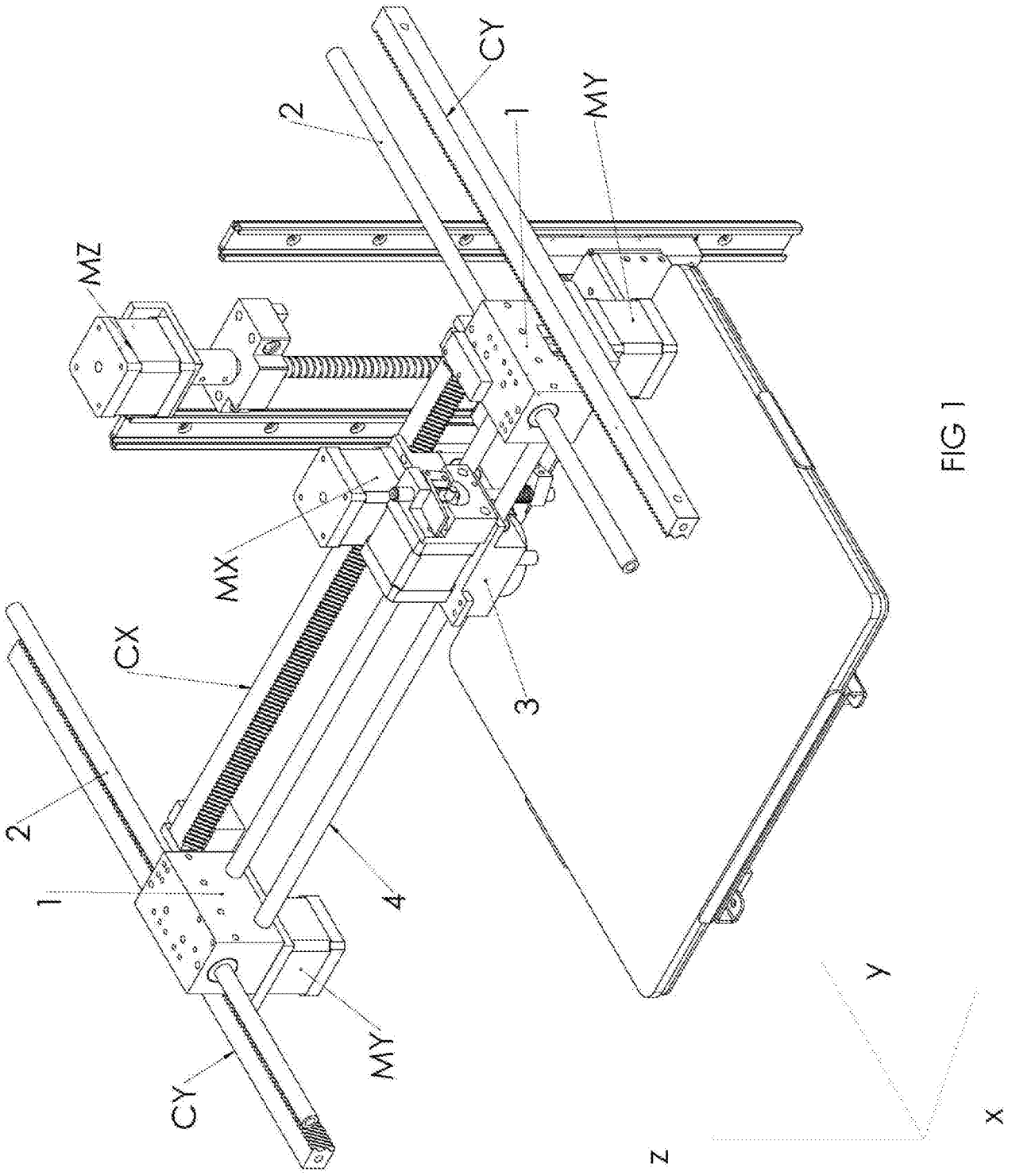

FIG 1

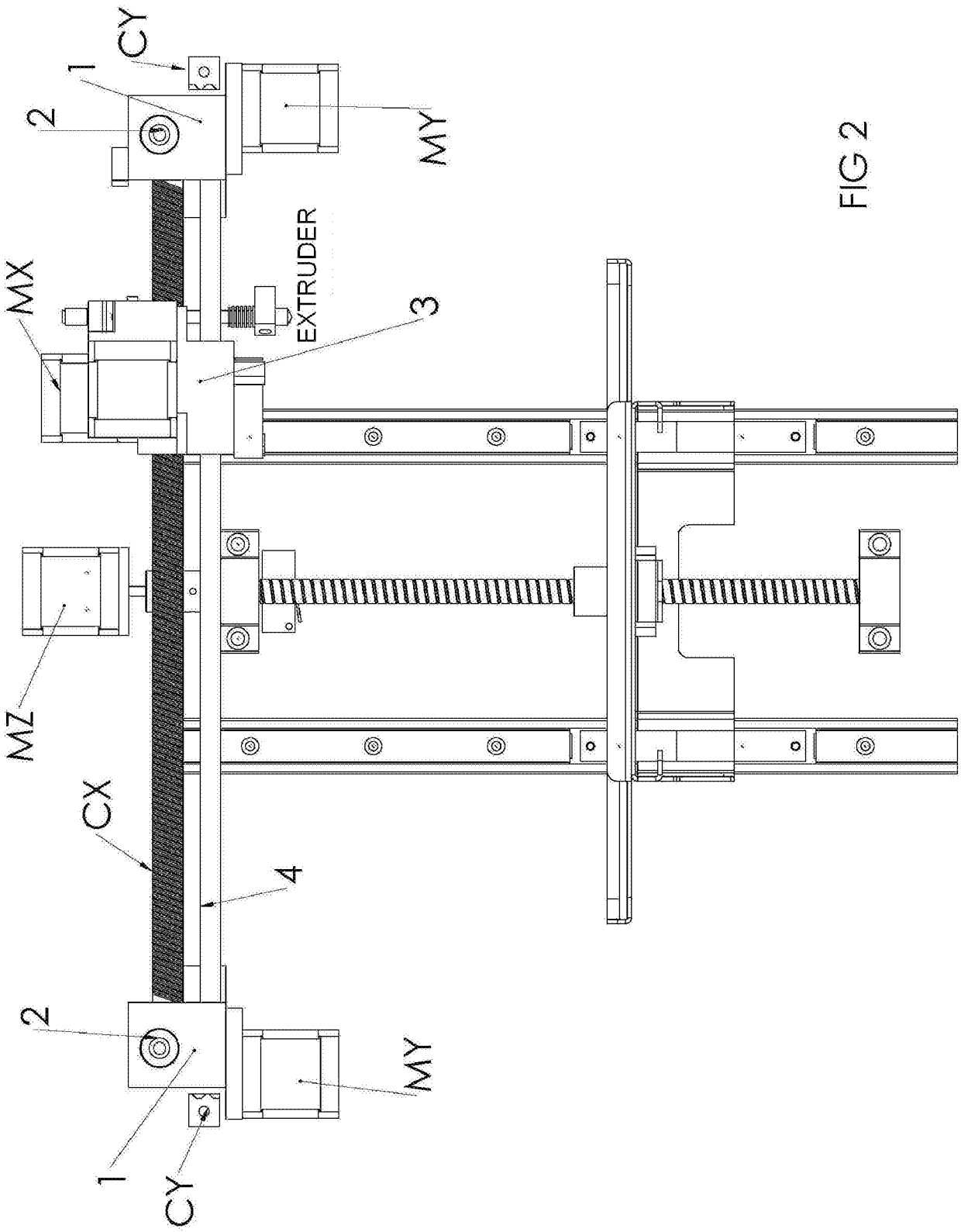

FIG 2

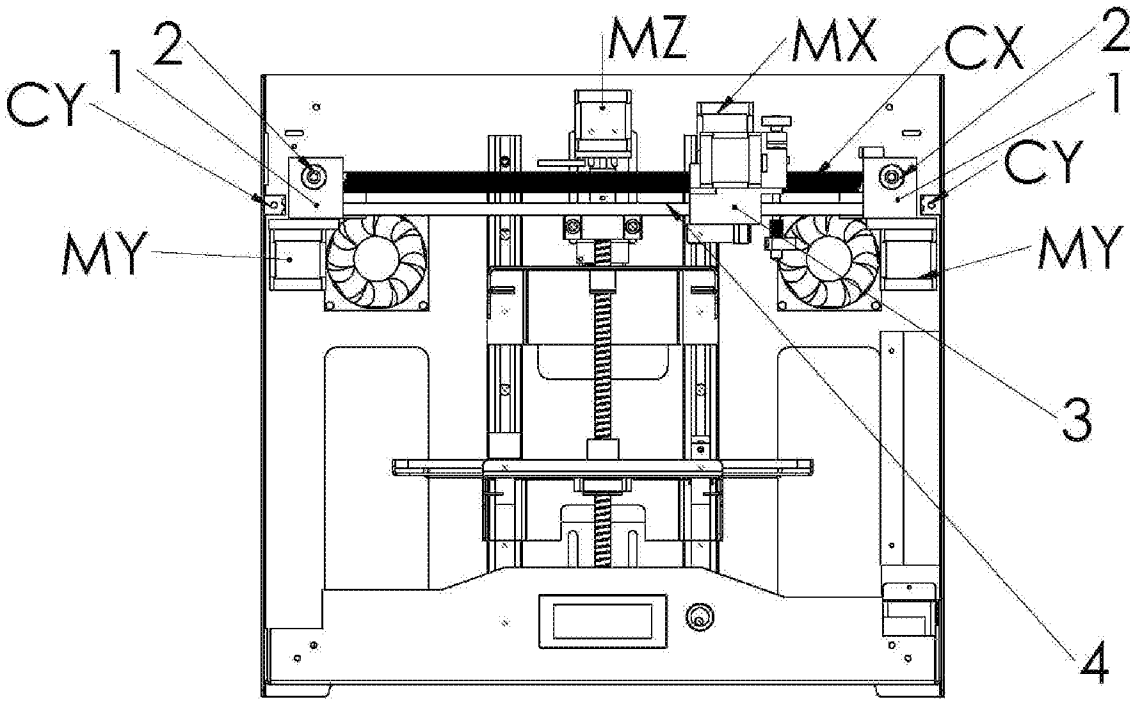

FIG 3

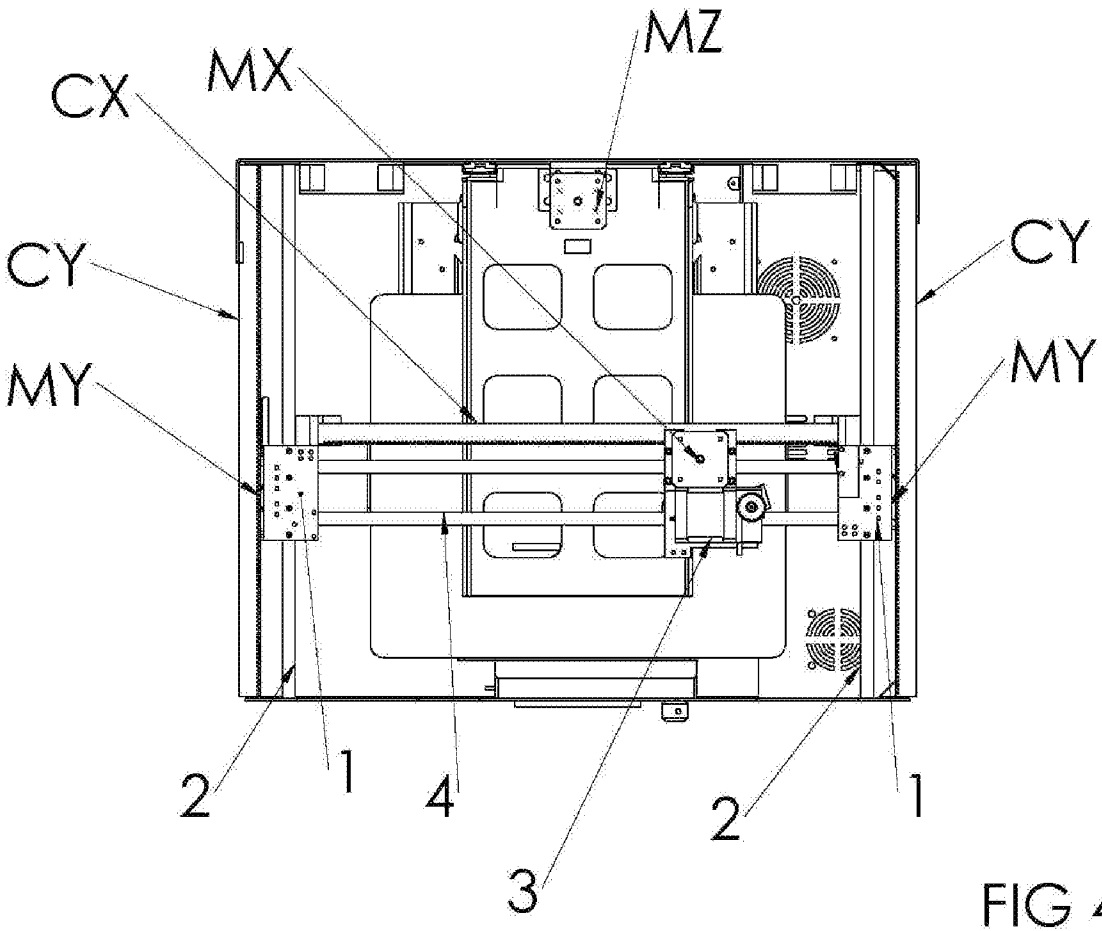

FIG 4

INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2016/051447

A. CLASSIFICATION OF SUBJECT MATTER
INV. B29C67/00 B33Y30/00
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
B29C B33Y

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	Whitney Hipolite: "Introducing the Roboze One 3D Printer -- 'Italy's First Professional 3D Printer'", , 1 March 2015 (2015-03-01), XP002758815, Retrieved from the Internet: URL:http://3dprint.com/47651/roboze-one-3d-printer/ [retrieved on 2016-06-15]	1-3,9
Y	See also http://web.archive.org/web/20150301140525/http://3dprint.com/47651/roboze-one-3d-printer/ for proof of publication on 01-03-2015	4-8,10, 11
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[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
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INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2016/051447

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	EP 2 617 554 A1 (OKKA HAKAN [DE]; JOVANOVIC MIRJANA [DE]) 24 July 2013 (2013-07-24) paragraph [0011]; figures	4-8,10, 11
Y	DE 10 2009 056696 A1 (PROMETAL RCT GMBH [DE]) 9 June 2011 (2011-06-09) paragraph [0013]	10,11

1

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/IB2016/051447

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP 2617554 A1	24-07-2013	DE 102012000664 A1	18-07-2013
		EP 2617554 A1	24-07-2013
DE 102009056696 A1	09-06-2011	DE 102009056696 A1	09-06-2011
		EP 2391499 A2	07-12-2011
		US 2013004607 A1	03-01-2013
		WO 2011067352 A2	09-06-2011