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[Continued on next page]

(54) Title: A METHOD FOR ADDITIVE MANUFACTURING OF A SPATIAL 3D OBJECT AND A DEVICE FOR ADDITIVE MANUFACTURING OF A SPATIAL 3D OBJECT

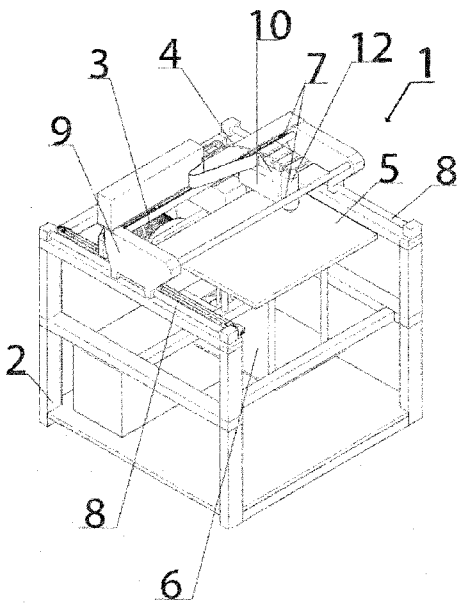

Fig.1

(57) Abstract: The invention provides a method of additive manufacturing of a spatial 3D object and a device for additive manufacturing of a spatial 3D object, in particular for additive manufacturing of three-dimensional objects in color. A method of additive manufacturing of a spatial 3D object, in which consecutive layers are formed, by depositing a layer of material on a model base at places corresponding to a cross-section of the 3D object for such layer. Thus obtained layer is cured, and a next layer is formed thereon upon movement of the 3D object being built along with the model base by a level corresponding to the thickness of the layer being formed. On the formed layer color is applied. A device (1) for additive manufacturing od a spatial 3D object comprises a frame (2), a tank (3) with material (4) to be fed, seated in the frame, a head (12) for dispensing a layer of material (4) seated on guides (7), a model base (5) movable vertically by an elevating system (6). In the frame (2) on upper guides (7) a printing head (10) is seated.

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A method for additive manufacturing of a spatial 3D object and a device for additive manufacturing of a spatial 3D object

The present invention provides a method for additive manufacturing of a spatial 3D object and a device for additive manufacturing of a spatial 3D object, in particular for manufacturing of three-dimensional colored objects, where 3D manufacturing is effected by incremental method.

Additive manufacturing of three-dimensional objects in color is presently broadly used, and one of such uses involves faster design developing operations that make it possible to produce prototype elements by additive manufacturing thereof based on a digital model that is machine generated and stored.

This invention provides general improvements in a method and device for forming three-dimensional objects of a thermoplastic medium that undergoes temperature-induced softening or of a medium in a form of a paste of a semi-fluid consistence and capable to be transfer-molded, in particular in color, in a method of depositing successive layers by defining their shape in the object being built, comprising the use of techniques for manufacturing three-dimensional objects, where such objects may be formed faster, reliably and economically.

This is a commonly applied practice in manufacture of parts of plastics, as well as in the construction process, which is for first construction of such parts, and then careful manufacture of a prototype. All the known methods require considerable time and effort as well as costs.

The project is then analyzed and often it is a laborious process that is repeated again and again until the construction becomes optimized. The stage of optimization of the design, is followed by the step of manufacturing. The major part of the manufacture is effected by injection method. Design and equipment costs are very high and plastics parts are usually practically useful solely in large scale batch production.

In the recent years, very complex techniques for creating three-dimensional objects have been developed, both with the use of thermoplastic materials and in a form of a paste, that are built layer by layer, where an individual layer may have a thickness roughly of 0.1 mm.

From the US patent specification 51211329 a system is known for forming three-dimensional objects where layers corresponding to digital cross-sections of the object being made are formed.

From KR101346704 a solution is known concerning color printing in the FDM technology. Color of an object is created at the stage of mixing strands of thermoplastics having different basic colors. The solution, however, has sharp color boundaries and requires a minimum size of the "pixel" of a color; it has a limited range of reproduced colors, and therefore the quality of print of complex graphics is limited, and it takes a long time to print.

From WO2005000592 a solution is known wherein an ink-jet head moves over a 3D object, adapting itself to its shape and printing color on selected segments. This makes it possible to print, for example, a model of mountains. A 3D printer according to this solution doesn't allow to color undercuts. It works in the XYZ axes, which makes problematic or even impossible to color the walls with angles close to 90 degrees and larger. In summary, the 3D printer according to this solution, is used only to color ready-made objects.

The main object of the invention of this document is to provide a method and device by which a three-dimensional object may be created in short time and in a cost-effective manner.

It is contemplated that the invention is particularly useful in manufacturing prototypes or models for individual products so that they may be formed and examined fast by the designers.

Products of complex shapes may be thus effectively and productively examined in the course of direct inspection when focusing at construction faults and by re-modeling.

These main objectives are achieved by feeding a material, the 3D object is being built from, at a controlled speed from a dispensing head from the substrate or base element in a preset pattern determined by the shape of the product. The 3D object may be formed from a dispensed material from numerous layers that are cured and adhere to each other in order to form the product.

The solutions known from the prior art use also devices that enable carrying out the above method for the preparation of spatial 3D models. In the known devices for incremental additive manufacturing of spatial 3D objects, in a frame constituting a body of the device, an operational tank is provided accommodating a medium that is the material from which successive layers are to be formed. The material is dispensed from a head that is preheated to obtain a semifluid consistence if the material is thermoplastic. After a successive layer is formed, the thermoplastic material is cured under ambient temperature.

In another embodiment, material having a paste consistence is extruded of a nozzle of a device, in order to form another layer. The paste may have diverse properties and suitably to the intended use it may be cured, after a layer of the 3D object being built is deposited, by varied methods.

As mentioned above, a spatial 3D object is formed by means of consecutive layers formed "from the bottom", where these layers are defined by a digital form obtained in a computer system during design work on the spatial model.

Known devices do not enable coloring of the 3D model being built in a satisfactory manner. In these devices this is in practice possible solely by selection of a thermoplastic material or in a form of a paste in suitable color. Also such formed model may be painted outside, after it is removed from the device, in another technological method.

It is thus an object of the invention to provide a method and device that would alleviate imperfections and inconveniences of the methods and devices of the prior art and to propose new methods and devices in this technical field.

The object of the invention is a method for additive manufacturing of a spatial 3D object, where consecutive layers are formed by depositing a layer of a material on a model base at positions that correspond to a cross-section of the 3D object for such layer. Thus obtained layer is cured and thereon a subsequent layer is formed upon movement of the 3D object being built along with the model base by a level corresponding to the thickness of the layer being formed. On thus formed layer color is applied.

Preferably, consecutive layers are formed by depositing a layer of thermoplastic material.

Preferably, the thermoplastic material in a form of a wire is fed from a reel that constitutes a tank of material deposited.

Also preferably, consecutive layers are formed by depositing a layer of a material in a form of a paste.

Also preferably, thermoplastic material in a form of a paste is taken from a tank of material being deposited.

Preferably, consecutive layers are formed by extrusion of the material.

Also preferably, such extruded material is given a desired absorbing capacity and porosity.

Also preferably, color is applied on a formed layer by means of an ink head.

Also preferably, color is applied by means of an ink head that comprises cartridges with the CMYK palette.

Also preferably, color applied by means of an ink head (10) is a UV-curable ink.

Also preferably, color is applied solely onto selected segments of a layer.

Also preferably, before color is applied on a layer priming agents are coated.

Also preferably, consecutive layers are formed by the method of depositing melt material FFF (fused filament fabrication).

Preferably, the process of additive manufacturing of a spatial 3D object is carried out under control of a computer program.

Another object of the invention is a device for incremental additive manufacturing of a spatial 3D object, comprising a frame, a tank with material to be fed, seated in the frame, a head for dispensing a layer of material and seated on guides, a model base movable vertically by an elevating system. In the frame, on upper guides a printing head is seated.

Preferably, the printing head is provided with at least one cartridge that comprises a coloring agent.

Also preferably, the printing head is a thermal head.

Also preferably, the printing head (10) is a piezoelectric head.

Also preferably, the printing head is a memjet-type head.

Preferably, the printing head is arranged on a carriage seated in the frame of the device and the carriage is arranged movably on lower guides.

Also preferably, the device is provided with a parking station for the printing head.

Also preferably, the parking station for the printing head is provided with a cleaning liquid sprinkler for the printing head and with a container for the used cleaning liquid and ink.

The object of the invention is illustrated in its non-limiting embodiment in the drawing, where Fig. 1 shows a device for additive manufacturing of a 3D object in a perspective view from one side of the model base; Fig. 2 shows a device for additive manufacturing of a 3D object in a perspective view from the other side of the model base; Fig. 3 shows a device for additive manufacturing of a 3D object in a perspective view from one side of the material tank; Fig. 4 shows a device for additive manufacturing of a 3D object in a perspective view from the other side from the side of the material tank; Fig. 5 shows a segment of a device in a perspective view, illustrating the time when a layer is being formed by a head; Fig. 6 shows a segment of a device in a perspective view, illustrating the time when color is applied by a printing head on a formed layer; and Fig. 7 shows a segment of a device in a perspective view, showing the time when color is applied by a printing head on a next formed layer where also preceding formed layers are also visible.

As shown in Fig. 1, Fig. 2, Fig. 4, Fig. 4, in this embodiment, a base of a device 1 for additive manufacturing of a spatial 3D object is constituted by a body in a form of a spatial frame 2 made of metal shaped sections. In the frame 2 of the device 1 a tank 3 is arranged for a material to be used for building a 3D object in a method consisting on applying consecutive layers. In this embodiment, the tank 3 is a reel on which thermoplastic material in a form of a wire is wound, where the material softens at elevated temperatures and becomes

plastic. The thermoplastic material, upon deactivation of elevated temperatures solidifies again.

In the frame 2 of the device 1 a model base 5 is placed on which a 3D model is built from the thermoplastic material fed from the tank 3, by forming its consecutive layers. The model base 5 is seated in an elevating system 6 which is composed of a transmission assembly with worm guides coupled with a step motor. The elevating system 6 is intended to elevate and lower the model base during building consecutive layers of the 3D object that correspond to respective cross-sections of the model. These cross-sections may be recorded in an electronic form for a respective layer of the 3D object stored in a computer control system for the device 1 inside the tank 3 for the thermoplastic material. The elevating system thus has to enable very precise, and what is more important, by a very small pitch of even below 0,1 mm, movement of the model base and the 3D object being built thereon.

In the embodiment shown in Fig. 1, Fig. 2, Fig. 3, and Fig. 4, the frame 2 of the device 1 is provided with lower guides 8 placed at two opposite sides of the device 1. On the lower guides 8 a carriage 9 is seated that is movable along these sides of the device 1 with lower guides 8.

The carriage 9, the ends of which move on lower guides 8, is equipped with upper guides 7, perpendicular to the lower guides 8. On the upper guides 7 of the carriage 9 an extruder 12 is movable which is constituted by an extruding head with a heating circuit (not shown). To the extruder 12 the thermoplastic material 4 is fed in a form of a wire. The thermoplastic material is fed to the extruder 12 from a tank 3 which in this embodiment is a roll on which the thermoplastic material 4 in a form of a wire is wound.

Apart from the extruder 12, on the upper rollers 7 of the carriage 9 a printing head 10 is movable provided with cartridges 11 comprising a coloring agent in different colors. When a layer of the thermoplastic material is formed

corresponding to a specific cross-section of the 3D object being built, over such layer w_n the coloring head is moved to apply color on the formed layer w_n.

During forming a subsequent layer w_n of the 3D being built by extrusion from the extruder of the elevated temperature-softened thermoplastic material 4, its surface may be given a special structure, for example porous texture, so as to enable penetration of the coloring agent from the cartridges 11 of the coloring head 10 inside the structure of the thermoplastic material 4 so as to obtain a specific visual effect.

The printing head 10 comprises four cartridges 11 with coloring agent in varied colors which enables obtaining a very broad set of colors available for printing as a result of combining colors from different cartridges.

Unused printing head 10 is retained in a parking station 13 that may be provided with means for cleaning the heads (not shown) and with a container for accessories used.

As shown in Fig. 5, the extruder forms on the model base 5 consecutive layers w_n of the 3D object being built. From the extruder 12 a batch of thermoplastic material 4 is extruded in a form of a wire which has been pre-heated to its softening point. A layer w_n of a required shape corresponding to the cross-section of the 3D object is deposited in a form of thin strips of a specific thickness that may be equal to or greater than 0.1 mm.

After the layer w_1 is formed (it may be assumed that Fig. 5 shows a layer formed directly on the model base), the printing head 10 from the cartridge 11 applies the coloring agent onto the desired areas of the layer w_1. This step of forming a 3D object is shown in Fig. 6. Color does not have to be applied on the entire layer w_n, and it can solely affect solely selected segments. In this embodiment, color is applied by means of a printing head 10 which is constituted by an ink head with cartridges 11. The printing head 10 is an ink head of a

thermal type, but it may be another kind of head, for example a piezoelectric head or some other head.

Fig. 7 shows several layers w_n arranged suitably to cross-sections of the 3D object, where it may be seen that on the consecutive layers w_n color is applied in a varied way than in the preceding layers.

Suitably to the needs, before color is applied on a layer w_n, the layer may be coated before and for this purpose the device 1 has to be equipped with an application to enable such operations, not shown in the drawing.

Printing head 10 comprises four cartridges 11 with a coloring agent in varied colors which enables obtaining a very broad set of available printable colors as a result of suitable combining colors from various cartridges.

Device 1 for additive manufacturing of a spatial 3D object, in this embodiment, is controlled by a computer system where a digital form of the 3D object being built is stored. The computer program controls thus substantially operation of all the assemblies of the device 1, and in particular the positioning of the model base 5, the thickness of the material layer being deposited, the movement of the printing head 10 and the deposition of color thereby, as well as the process of cleaning of the printing head 10 in the parking station 13.

It is obvious that the elevating system 6 shown in this embodiment may be substituted by another solution to fulfill the same functions, as for example a solution with a scissors mechanism.

The embodiments of the invention shown herein, related both to a method for additive manufacturing of a spatial 3D object and to a device for additive manufacturing of a spatial 3D object, are provided herein solely for non-limiting indication purposes and they cannot limit in any way the scope of protection as defined in the patent claims.

Claims

1. A method for additive manufacturing of a spatial 3D object, in which consecutive layers are formed by depositing a layer of a material on a model base at positions that correspond to a cross-section of the 3D object for such layer, where thus obtained layer is cured and thereon a subsequent layer is formed upon movement of the 3D object being built along with the model base by a level corresponding to the thickness of the layer being formed, **characterized in that**

   - on a consecutive formed layer color is applied.

2. A method of claim 1, **characterized in that** consecutive layers are formed by depositing a layer w_n of a thermoplastic material.
3. A method of claim 2, **characterized in that** thermoplastic material in a form of a wire is fed from a reel that constitutes a tank (3) of the material being deposited.
4. A method of claim 1, **characterized in that** consecutive layers w_n are formed by depositing a layer w_n of material in form of a paste.
5. A method of claim 4, **characterized in that** the thermoplastic material in form of a paste is taken from a tank (3) of the material being deposited.
6. A method of claim 1, **characterized in that** consecutive layers w_n are formed by extrusion of the material.
7. A method of claim 6, **characterized in that** the extruded material is given a desired absorbing capacity and porosity.
8. A method of claim 1, **characterized in that** color is applied on a formed layer w_n by means of an ink head (10).

9. A method of claim 8, **characterized in that** color is applied by means of an ink head (10) comprising cartridges (11) with a CMYK palette.
10. A method of claim 8, **characterized in that** color applied by means of an ink head (10) is a UV-curable ink.
11. A method of claim 1, **characterized in that** color is applied solely onto selected segments of a layer w_n.
12. A method of claim 1, **characterized in that** before color is applied on a layer w_n, priming agents are coated.
13. A method of claim 1, **characterized in that** consecutive layers w_n are formed by the method of depositing melt material FFF (fused filament fabrication).
14. A method of claim 1, **characterized in that** process of additive manufacturing of a spatial 3D object is carried out under control of a computer program.
15. A device for incremental additive manufacturing of a spatial 3D object, comprising a frame, a tank with material to be fed, seated in the frame, a head for dispensing a layer of material, seated on guides, a model base movable vertically by an elevating system, **characterized in that** in the frame (2) on upper guides (7) a printing head (10) is seated.
16. A device of claim 14, **characterized in that** the printing head (10) is provided with at least one cartridge (11) that comprises a coloring agent.
17. A device of claim 14, **characterized in that** the printing head (10) is a thermal head.
18. A device of claim 14, **characterized in that** the printing head (10) is a piezoelectric head.
19. A device of claim 14, **characterized in that** the printing head (10) is a memjet-type head.

20. A device of claim 14, **characterized in that** the printing head (10) is arranged on a carriage (9) seated in the frame (2) of the device (1), and the carriage (9) is arranged movably on lower guides (8).
21. A device of claim 14, **characterized in that** it is provided with a parking station (13) for the printing head (10).
22. A device of claim 20, **characterized in that** the parking station (13) for the printing head (10) is provided with a cleaning liquid sprinkler for the printing head (10) and with a container (14) for cleaning liquid and ink used.

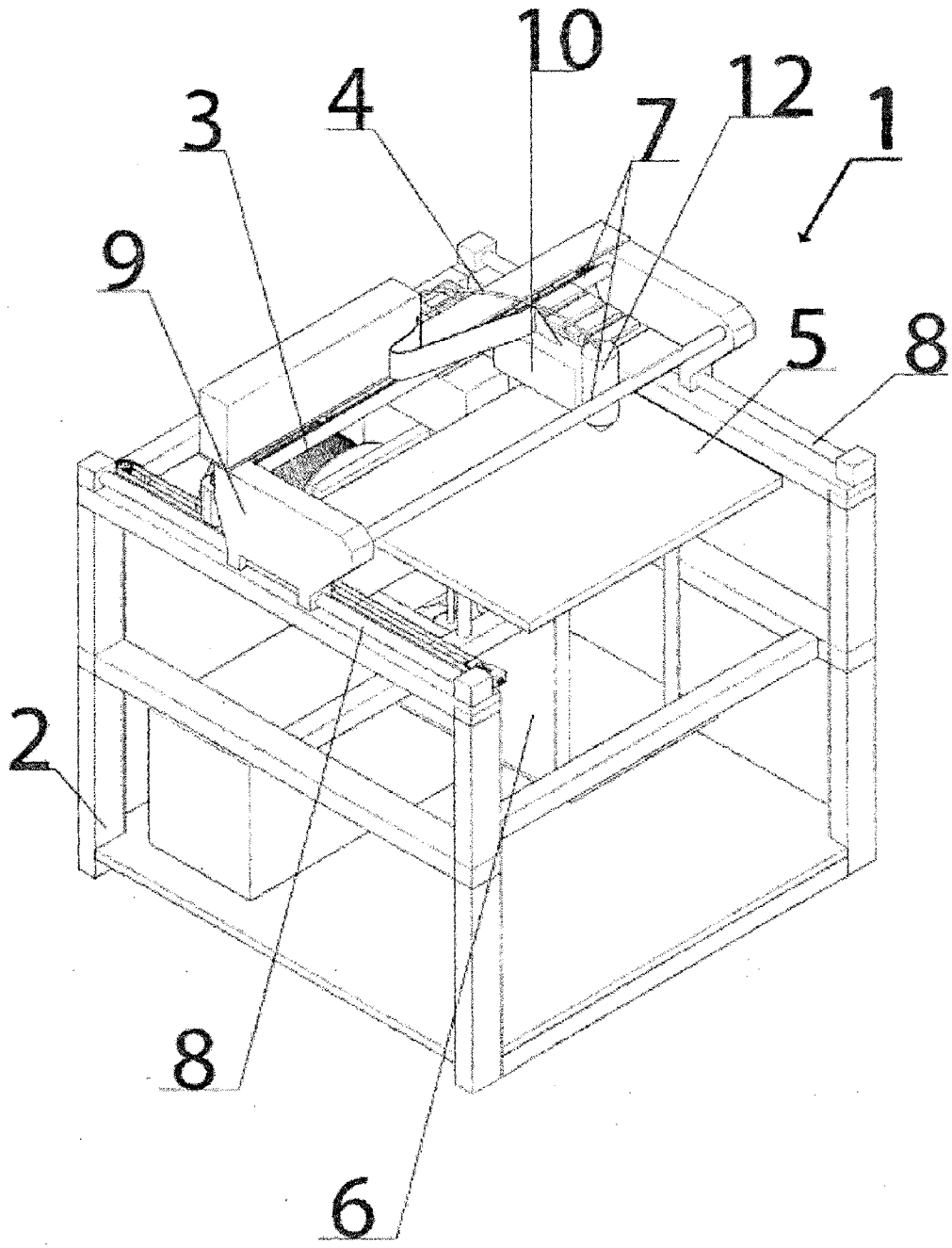

Fig.1

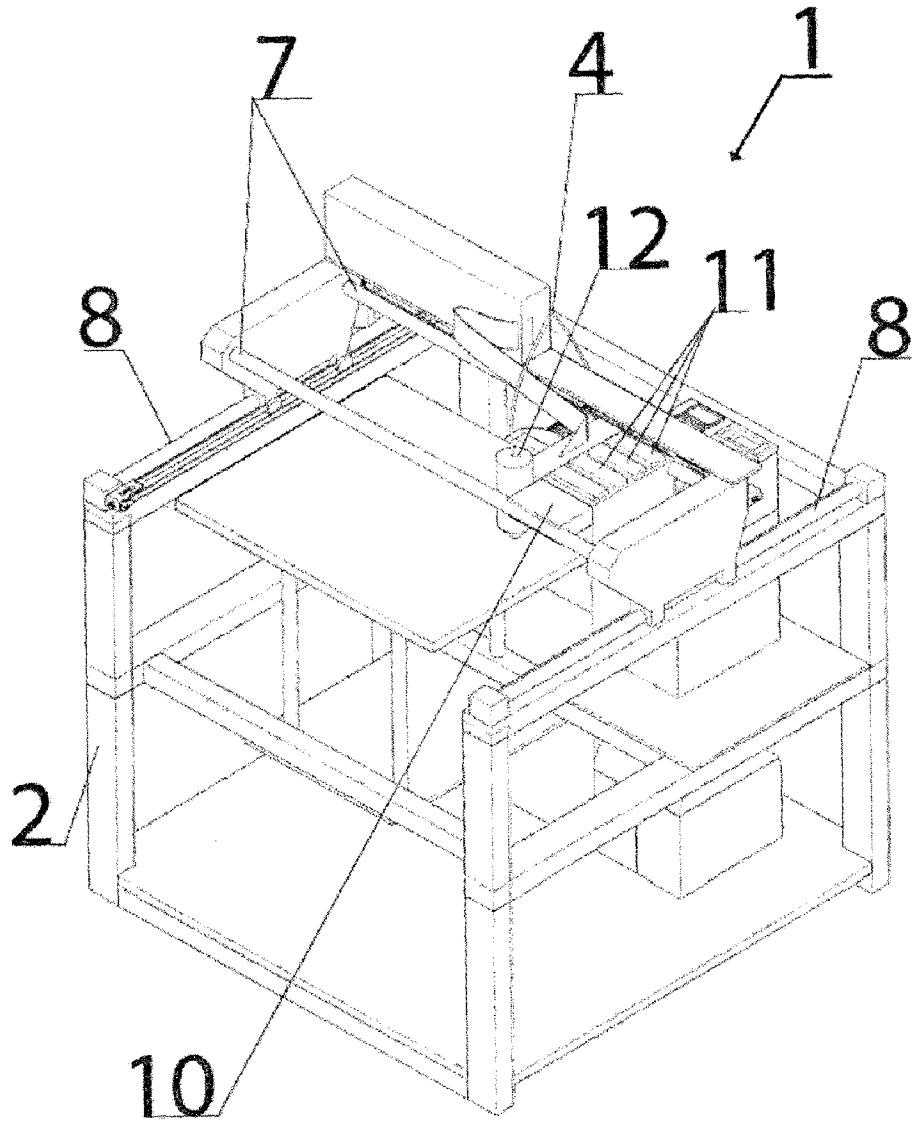

Fig.2

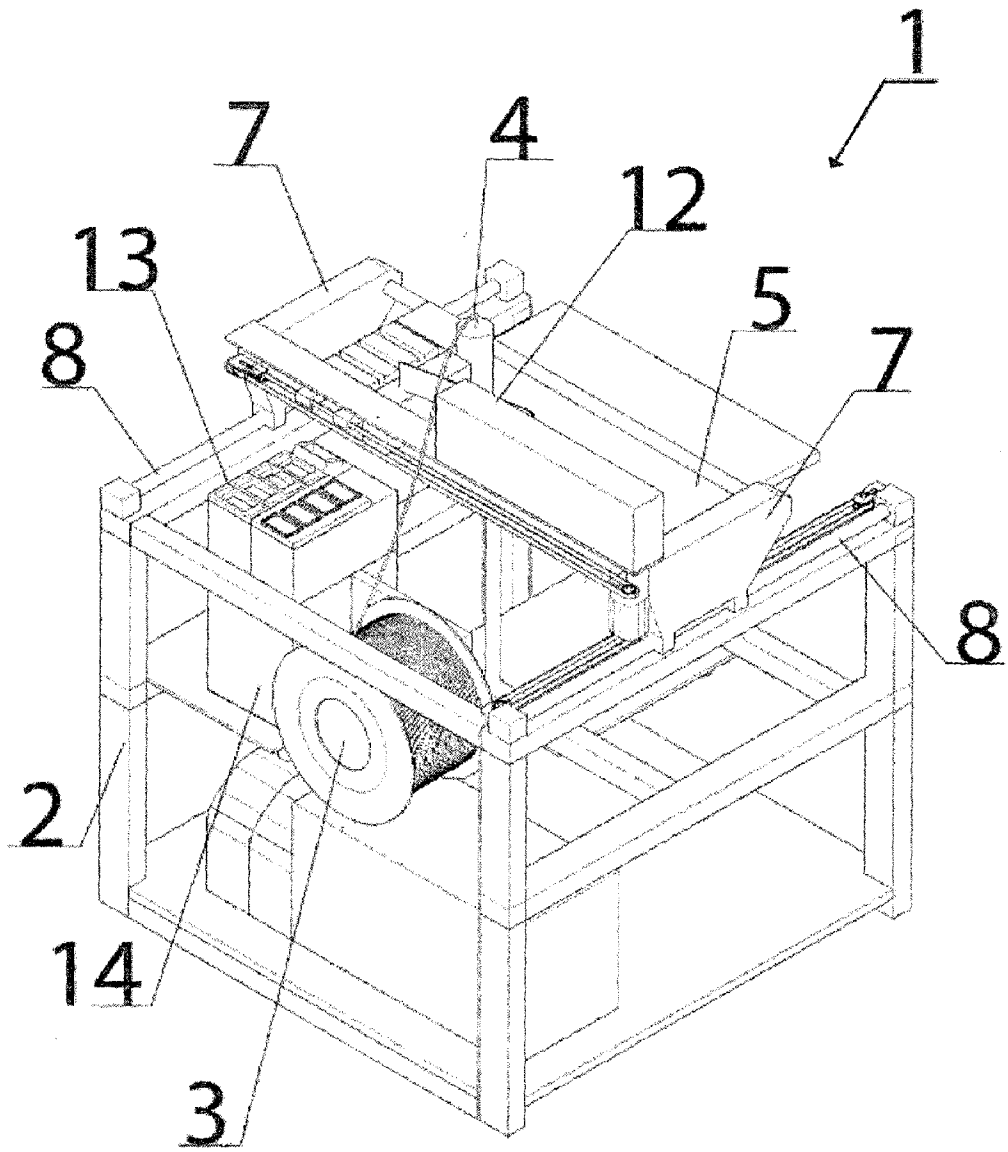

Fig.3

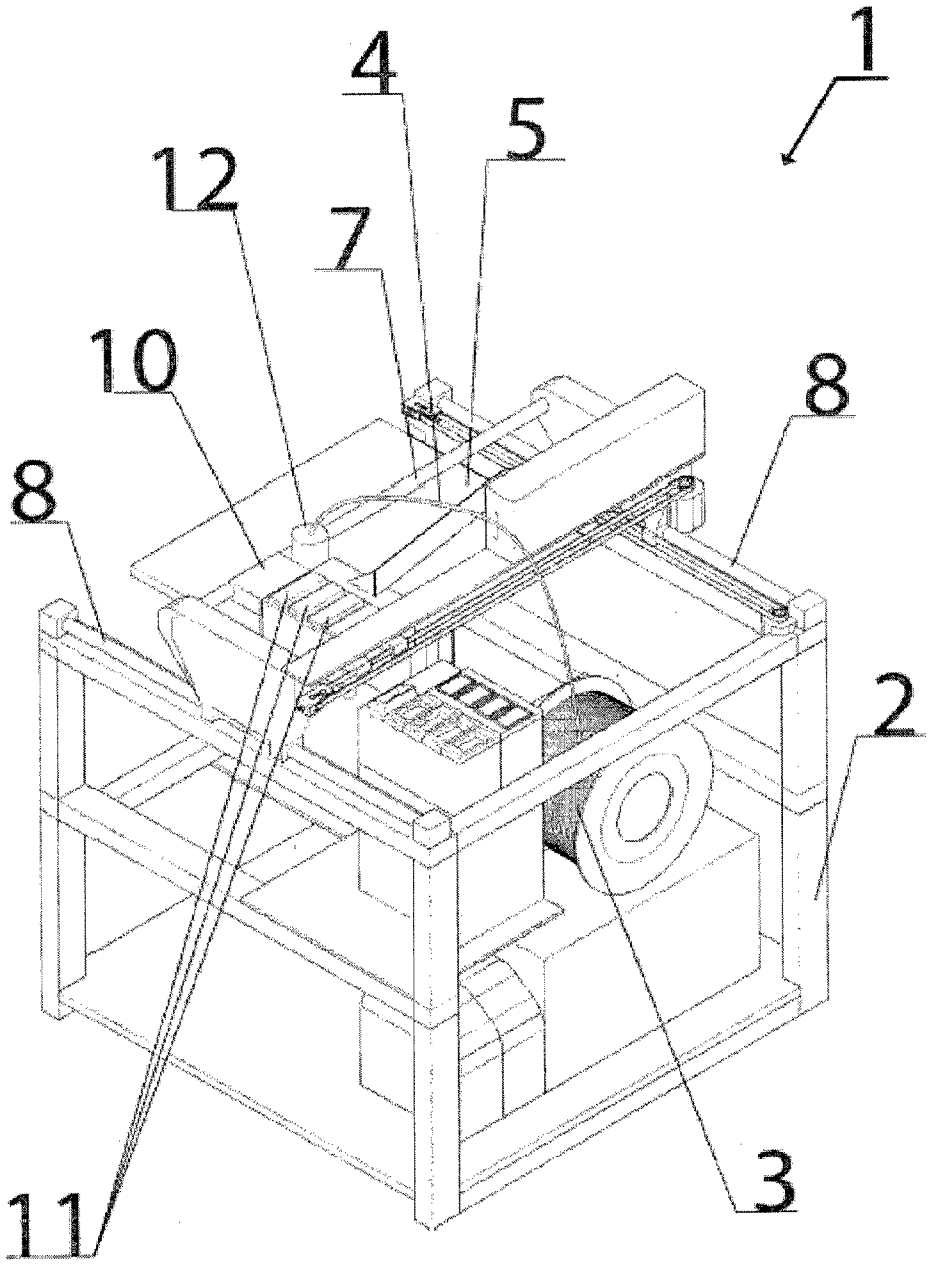

Fig.4

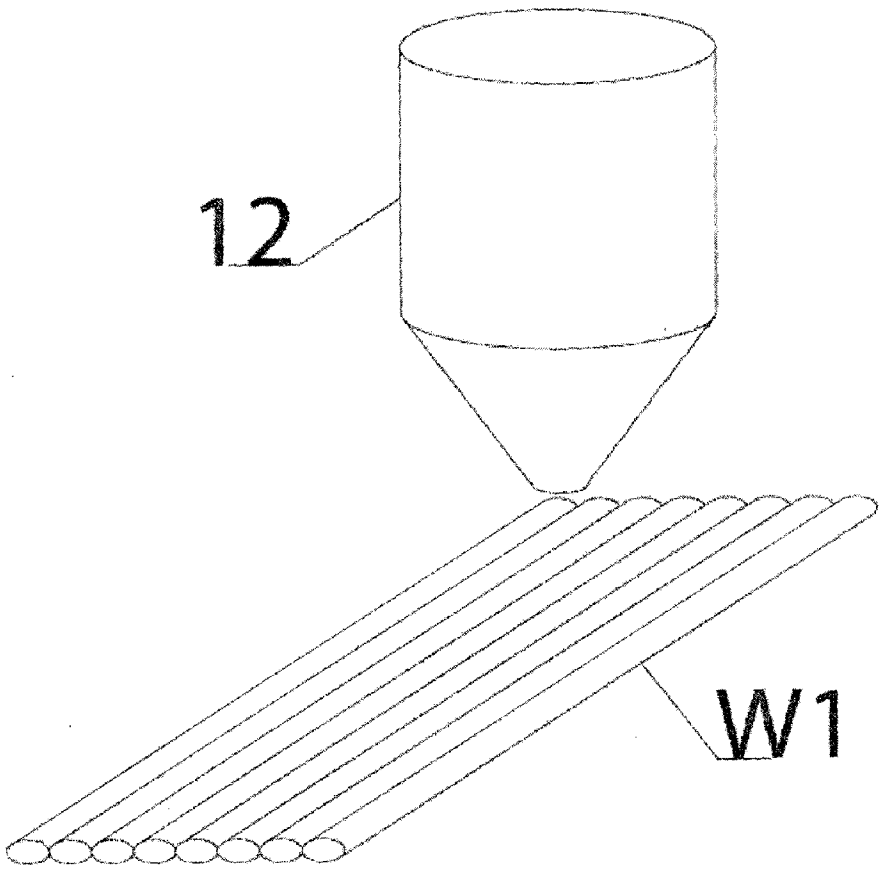

Fig.5

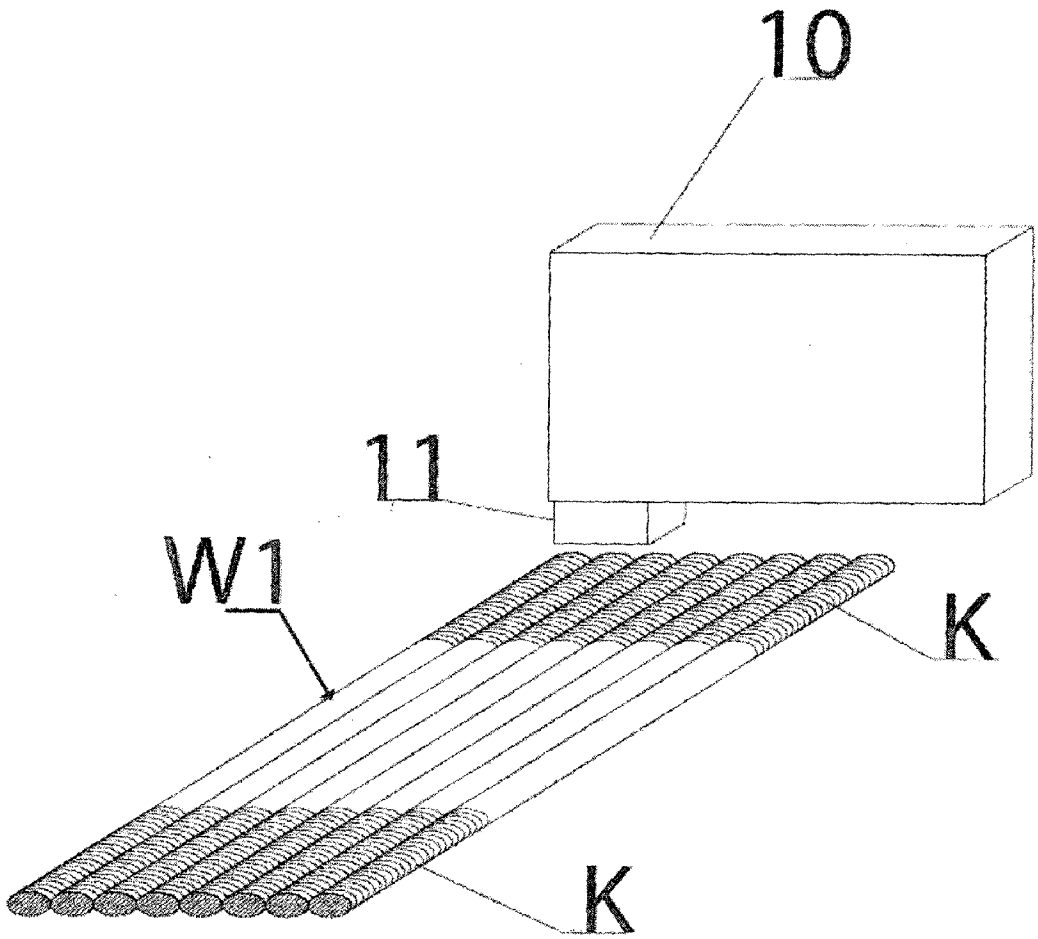

Fig.6

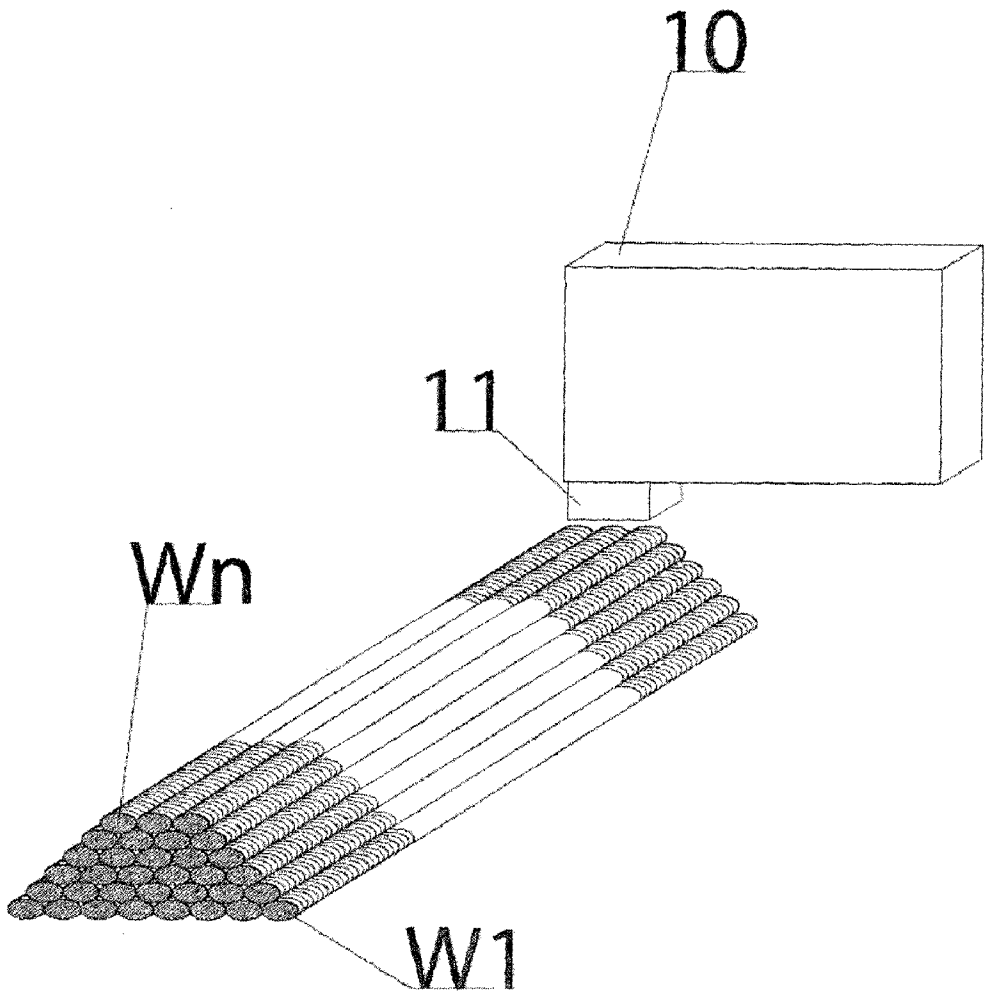

Fig.7

INTERNATIONAL SEARCH REPORT

International application No
PCT/PL2015/000065

A. CLASSIFICATION OF SUBJECT MATTER
INV. B29C67/00 B33Y10/00 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, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2012/058278 A2 (GILLER EUGENE [US]) 3 May 2012 (2012-05-03)	1,2,4, 6-8,10, 12-22
Y	figure 2 page 2, paragraphs [0006], [0008] page 7, paragraphs [0027], [0038] page 8, paragraph [0032] page 12, paragraph [0044] page 15, paragraph [0051] -----	3
X	EP 2 455 211 A2 (SONY CORP [JP]) 23 May 2012 (2012-05-23) figures 1, 5A, 5B column 2, paragraphs [0010], [0011], [0014] column 10, paragraph [0069] -----	1,5, 8-11,14, 15,20-22
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[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

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Date of the actual completion of the international search	Date of mailing of the international search report
3 July 2015	10/07/2015

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Gasner, Benoit

1

Form PCT/ISA/210 (second sheet) (April 2005)

INTERNATIONAL SEARCH REPORT

International application No
PCT/PL2015/000065

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2012/258250 A1 (RODGERS LUKE M B [US]) 11 October 2012 (2012-10-11) figure 1 -----	3

1

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/PL2015/000065

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