

COMPONENTS FOR USE IN THREE DIMENSIONAL FABRICATORS

REFERENCE TO RELATED APPLICATION

This applicant claims the benefit of Singapore patent application number
5 201207174-2, filed 26 September 2012; the contents of which are
incorporated by reference herein.

FIELD OF THE INVENTION

The present invention relates to components suitable for (but not limited to)
use in three dimensional fabricators, such as three dimensional (3D) printers.
10 In particular, the components relate to filament material dispenser and a
support structure for facilitating the depositing of filament on a three
dimensional printer.

BACKGROUND ART

The following discussion of the background to the invention is intended to
15 facilitate an understanding of the present invention. However, it should be
appreciated that the discussion is not an acknowledgment or admission that
any of the material referred to was published, known or part of the common
general knowledge in any jurisdiction as at the priority date of the application.

Thermoplastic extrusion methods have become one of the most commonly
20 used additive fabrication technologies. The operation of a typical three
dimensional (3D) printer comprises the step of unwinding filament material
(such as plastic) from a coil and supplying the material to an extruder. The
extruder is heated to melt the plastic and has a mechanism which allows the
flow of the melted plastic to be turned on and off. The extruder is mounted to a
25 platform (mechanical stage) which can be moved in both horizontal and
vertical directions, hence creating a three dimensional structure.

As the plastic filament material needs to be unwound to avoid twisting and
entanglement, 3D printer filament spools are typically side dispensing.

Side dispensing spools however meant that the filament spools are mounted as side attachments to the 3D printer machine and the filament from the spool is fed into the 3D printer from a side. The side attached filament spools are generally not factored in as part of the 3D printer machines' overall design.

5 As such, the overall 3D printer machines with side attached filament spools are usually bulky, cumbersome and awkwardly shaped which makes it difficult to be stored without removing the side filament spools. In addition, 3D printer filament spools generally require manual loading of the filament on the spool. Manual loading involves taking a loose end of a predetermined length of
10 filament and threading it into the machine via a feeding tube, also known as a "Bowden Tube".

Various ways have been used to alleviate the manual loading and cumbersome/bulky design, including specially designed filament spool mounts for mounting to the bottom of the 3D machines and automating the loading of
15 the filament. The resulting design is thus a regular cube or cuboid shaped structure which is less bulky and cumbersome. However, such machines with bottom loading are generally complicated and incur a higher cost of production. Moreover, a bottom loading system works against gravity and may be deemed to be ineffective from an energy consumption point of view
20 due to the need to work against gravity. As the filament is a consumable item, users who run out of filament have to purchase and replace the filament and spool. For customized spool with bottom loading, the cost of replacement may be high.

In addition to a filament dispenser, typical 3D printers comprise an extruder
25 operable to receive fabrication material from the filament dispenser; and a build platform for receiving the fabrication material deposited by the extruder for fabrication. The platform and extruder are movable relative to one another to facilitate the depositing of fabrication material to form the three dimensional product. To maximize the movement, the extruder and/or platform are
30 mounted on guides that extend along the length of the 3D printer. There, however exists a need to reduce the form factor and cost of the 3D printer,

such as by minimizing the length of the guides or removing the guides in its entirety without compromising the operation and precision of the 3D printing.

The present invention seeks to provide an apparatus, system and method of fabrication that alleviates the above mentioned drawbacks at least in part.

5 SUMMARY OF THE INVENTION

Throughout this document, unless otherwise indicated to the contrary, the terms "comprising", "consisting of", and the like, are to be construed as non-exhaustive, or in other words, as meaning "including, but not limited to".

- 10 In accordance with a first aspect of the invention there is a filament dispenser for use in a three dimensional fabricator comprising; a filament container for holding filament material, the filament container comprising an outlet; a filament dock operable to receive filament from the filament container via the outlet; wherein the filament container is arranged to be disposed within the
15 filament dock; the filament container further rotatable relative to the filament dock such that when filament material is received, the filament container is simultaneously rotated.

The rotational movement facilitates the movement of filament material while preventing entanglement of the filament.

- 20 Preferably, the outlet of the filament container is positioned at the centre of the filament container and the dock is operable to receive filament material from the centre of the filament container.

- Alternatively, the outlet of the filament container is positioned off-centre from the centre of the filament container, and the filament dock is operable to
25 receive filament material from the off-centre of the filament container.

Preferably, the rotation of the filament container disposed within the filament dock is facilitated by ball-bearings.

Preferably, at least one gimbal is positioned proximal the outlet.

- 30 In accordance with a second aspect of the invention there is a support for use in a three dimensional fabricator comprising; a mounting plate for an extruder

to be attached thereon; and a tongue portion operable to slide with respect to the mounting plate; the tongue portion operably connected to a build platform; wherein in operation, the distance between the build platform and the extruder is slidably adjustable between a first position and a second position; the first position corresponds to a default start state and the second position corresponds to an extended state.

Preferably, the build platform is integrally moulded with the tongue portion.

In accordance with a third aspect of the invention there is a three dimensional fabricator for fabricating objects comprising:- a housing; a control unit for receiving instructions from a user; a filament dispenser according to the first aspect of the invention; an extruder operably connected to the filament dispenser to receive filament material for fabrication; a support according to the second aspect of the invention; the support comprising the movable platform for receiving filament material deposited by said extruder; wherein the control unit operates the extruder and the movable platform to deposit fabrication material on the platform in a pattern according to received instructions.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will now be described, by way of example only, with reference to the accompanying drawings, in which:

Fig. 1 is a perspective view of an embodiment of the invention comprising a filament container, a filament dock and a feeding system;

Fig. 2a shows the embodiment from a bottom perspective, with filament emerging from the funnel, after it has passed through the feeding system;

Fig. 2b shows a side view of the embodiment, with filament emerging from the funnel, after it has passed through the feeding system;

Fig. 3 is a top view of the filament container depicted resting within the filament dock;

Fig. 4 is an exploded view of the filament container and filament dock;

Fig. 5 is a detailed exploded view viewed from bottom perspective comprising mechanical components;

Fig. 6 is another exploded view from a side perspective view;

- 5 Fig. 7A shows an exploded view of the embodiment with particular emphasis on the drive mechanism and the feeding mechanism enclosed within the feed system in more detail;

Fig. 7B shows an end view of the drive mechanism

- 10 Fig. 8A and 8B shows various configurations of filament containers (cartridges) that can be used with one or more gimbals.

Fig. 9A to 9D shows the support structure for use with a three dimensional fabricator in accordance with another embodiment of the invention in various perspectives.

- 15 Fig. 9E and 9F show the side views of the support structure for use with a three dimensional fabricator with other components attached thereto.

Fig. 10 shows an exploded view of the three dimensional fabricator.

Other arrangements of the invention are possible and, consequently, the accompanying drawings are not to be understood as superseding the generality of the preceding description of the invention.

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PREFERRED EMBODIMENT OF THE INVENTION

- Particular embodiments of the present invention will now be described with reference to the accompanying drawings. The terminology used herein is for the purpose of describing particular embodiments only and is not intended to
25 limit the scope of the present invention. Additionally, unless defined otherwise, all technical and scientific terms used herein have the same meanings as commonly understood by one of ordinary skill in the art to which this invention belongs.

In accordance with an embodiment of the present invention there is an apparatus 10 for dispensing filament 12 (see Fig. 1 and Fig. 2), in particular (but not limited to) dispensing filament 12 for use in a three dimensional fabricator, such as a 3D printer or a rapid prototyping machine.

The apparatus 10 comprises a filament container 14 for fitting into filament dock 60 and a feed system 80.

It is to be appreciated that the filament dock 60 and the feed system 80 may be integrated with an existing 3D printer or added as a separate modification to an existing 3D printer.

In the context of the invention, the term 'filament' or 'filament material' includes, but is not limited to polylactide (PLA) filaments in various dimensions (e.g. 3mm), colours, and enantiomers such as poly-D-lactide (PDLA), poly-L-lactide (PLLA), and mixtures of enantiomers in various ratios.

Referring to the exploded view of Fig. 4, the filament container 14 comprises a first portion 16 and a second portion 18. First portion 16 is preferably shaped as a circular plate. At the centre of the first portion 16 is formed a hole 20 for fitting a mandrel 22 (not shown) operable to coil filament. A plurality of protrusions 24 is disposed around circumference of first portion 16. The plurality of protrusions 24 is operable to be fitted for receiving slots 28 of the second portion 18 such that when fitted, the first portion 16 and second portion 18 of the filament container 14 forms a cylindrical container.

First portion 16 may further comprise a plurality of radial arms 26 for maintaining structural rigidity of the first portion 16.

Second portion 18 is formed as a container for storing the filament 12 and is shaped to receive the first portion 16. Second portion 18 comprises an outlet 30 for dispensing the stored filament and receiving slots 28 adapted or aligned to receive the plurality of protrusions 24. At the centre region of second

portion 18 is formed the outlet 30 for dispensing filament. The circumference of second portion 18 comprises a flange 32 formed to seat on guide wheels 62 of the filament dock 60. In operation, the flange 32 and guide wheels 62 allow the filament container 14 to rotate relative to the filament dock 60 while
5 dispensing the filament material.

The filament container 14 may be made of disposable material such as polypropylene (PP) or polylactic acid (PLA).

10 Filament dock 60 is shaped to receive or extract the filament container 14 therein. In the case of extraction, filament dock 60 may be integrated with an extractor to actively extract the filament material. In the embodiment the top of the filament dock 60 is a square shaped plate, but may be any other shaped plate to fit the overall design of the 3D printer as necessary. The
15 square shaped plate has a centre-depressed portion 61 to receive the filament container 14. Filament dock 60 comprises a plurality of guide wheels 62 and a funnel 64. Guide wheels 62 may be ball-bearings. Further details on cartridge configurations are described using a later drawing. When the filament container 14 is properly disposed or positioned within the filament
20 dock 60, the flange 32 of the filament container 14 contacts the guide wheels 62. Guide wheels 62 are operable to constrain the movement of the filament container 14 as well as facilitate the rotation of the filament container 14 about a common-centre axis of the filament container 14 and filament dock 60. Centre-depression 61 comprises a contour 66. Guide wheels 62 thus contact
25 the flange 32 of the filament container 14 and the contour 66 when the filament container 14 is positioned within the filament dock 60. The contour 66 ensures that the container cannot be loaded in an upside-down position and thus avoid operational errors arising from improper loading of the filament container 14. At the centre of the filament dock 60 there is a funnel 64 that
30 directs filament to the feed system 80. Funnel 64 is aligned with the outlet 30 when the filament container is positioned within the dock 60. Guide wheels 62 protrude from slots on the dock 60 to interface with the flange 32 on the

filament container 14. These guide wheels 62 may be mounted on vertical rods 63 which are a part of the filament dock 60.

5 The feed system 80 comprises a frame 81 and a spindle 82, preferably a flatted spindle. Spindle 82 is driven by a motor, preferably a stepper motor 92 for precision control. Frame 81 is preferably an aluminium frame. The flatted spindle 82 drives a worm gear 84. The worm gear 84 is driven to be biased against a spur gear 255. The spur gear 255 in turn drives a shaft 256. The other end of the shaft is attached to a drive gear 257, preferably a knurled
10 drive gear. Knurled drive gear 257 comprises teeth 258 operable to grip onto the filament 12 when filament 12 is passed through funnel 64. In this regard, filament 12 is operable to be passed through between a smooth plunger 86 and the knurled drive gear 257. During feeding the filament 12 is pressed by the teeth 258 and one side of the smooth plunger 86. The movement of teeth
15 258 in an appropriate direction (clockwise or anti-clockwise) pushes the filament 12 towards the drive mechanism and platform of the 3D printer.

The drive gear 257 is connected to a drive shaft 256. The drive shaft 256 is operable to transmit power from the motor 92 to the drive gear 257 to achieve
20 the purpose of regulating the quantity and/or speed of the filament output. The motor 92 is located in a corner adjacent to the filament dock 60. The motor 92 is orientated such that the flatted spindle 82 is operable to be in a vertical, downward pointing direction. Torque is transmitted from the motor 92 to the drive shaft 256 with the use of the worm gear 84; the worm gear 84
25 being fitted to the motor 92 which interfaces with a gear 255 fitted onto the drive shaft 256.

On the other side of the smooth plunger 86 is an electromagnet 88. The electromagnet 88 is operable to pull the plunger 86 away from the drive gear
30 257 when loading filament 12. A gap is required between the drive gear 257 and the plunger 86 during the loading process whereby filament 12 is loaded

into the 3D printer machine. Without this gap, filament loading would have to be done manually by pushing filament 12 against a spinning drive gear 257.

The present embodiment will next be described in the context of its operation.

5 A control algorithm implemented in the form of printer driver software may be used to control the loading and feeding of filament 12 into the 3D printer. A user may control the 3D printer via a user interface which comprises activating the 3D printer to operate between at least the following two modes:-

a 'loading' mode and

10 a 'feeding' mode.

Filament 12 is loaded by first inserting the leading end of the filament 12 into an inlet on the second portion 18 on the filament container 14. This leading end is attached to a mandrel inserted via the top plate central hole 20. The mandrel is spun, winding filament 12 into the filament container 14. When the
15 filament container 14 is filled with a predetermined amount of filament 12, the mandrel will be removed. The leading end is pushed through the central hole 30. At the opposing end, excess filament is trimmed off. Both leading and trailing ends are then bent to ensure it does not retract into the container 14.

20 In order to load the 3D printer with filament 12, a user activates the 'loading' mode. Upon activating the 'loading' mode, the printer triggers the electromagnet 88 in the feed system 80. The electromagnet 88 pulls the spring-loaded smooth plunger 86 away from the drive gear 257. As mentioned earlier, a sufficient gap is formed between the plunger 86 and the drive gear
25 257. This gap allows filament 12 from the filament container 14 to slip past the drive gear unimpeded.

The user then puts the filament container 14 into the filament dock 60. A length of exposed filament 12 will protrude from the bottom of the container
30 14. This exposed filament 12 slips into the funnel 64 at the bottom of the filament dock 60 and then enters the feed mechanism. Entry is unimpeded

due to the smooth plunger 86 having been pulled back by the electromagnet 88.

The user then disables the loading mode. Upon disablement, the electromagnet 88 is de-magnetized and the smooth plunger 86 returns to its original location where the gap is closed. This means the plunger 86 is now pressing the filament against the drive gear 257.

When the user activates the 'feeding' mode, the drive gear 257 activates teeth 258. Teeth 258 then begin to move the filament 12 towards the extruder system.

The interaction between the electromagnet 88 and smooth plunger 86 to achieve the loading mode and feeding mode is as follows:-

Smooth plunger 86 is spring loaded and biased against the electromagnet 88 such that when electromagnet 88 is activated and pulls the plunger 86 away from the drive gear 257, the spring is in a compressed state, creating the gap necessary for the 'loading' mode. When the electromagnet 88 is deactivated, the spring automatically returns to relaxed state, moving the smooth plunger 86 back towards the drive gear 257 and press against the filament.

The described invention is compact and has an automatic loading system for filament. The top down loading instead of side loading of filament provides a more compact design. The described filament container, dock, and feeder may be easily incorporated with existing 3D printers with some modification.

As the wound (coiled) filament 12 is pulled through the outlet 30 and funnel 64, a rotational force is generated. The resultant rotational force rotates the filament container 14 relative to the filament dock 60 and prevents entanglement of the filament 12 within the filament container 14.

To further facilitate rotation and to prevent entanglement of the filament 12 within the filament container 14, one or more gimbals 864 may be added in addition to the existing arrangement. The gimbal 864 may be positioned at the outlet 30 to account for any entanglement at the outlet 30. In operation, the gimbal(s) 864 may rotate or the filament container 14 rotates within the filament dock 60. In a situation where the mass of the filament container 14 is too heavy for effective rotation, the rotation of the gimbal 864 alleviates any entanglement. Fig. 8A shows the gimbal disposed at the outlet 30.

In accordance with another embodiment of the present invention, wherein like numerals reference like parts, there is an alternative filament container 820 and dock 840 for use with a three dimensional fabricator. In the alternative embodiment, the outlet 830 of the second portion is formed off-centre of the second portion 18, preferably near the circumference of the second portion 18. The funnel 64 of the filament dock 840 is formed accordingly to align with the outlet 830 formed at the second portion 18.

In operation, the filament material is pulled and dispensed from the direction B as indicated in Fig. 8B. As the filament material is pulled, the filament container rotates in the direction marked C.

In accordance with another embodiment of the present invention there is a support structure 900 for use in a three dimensional fabricator, such as a 3D printer, as shown in Figure 9A and 9B in a plan view and perspective view respectively. The movable support 900 is meant to replace the guides disposed along the length of the 3D printer as mentioned in the prior art.

The movable support 900 comprises a mounting plate 902 and a tongue portion 910 operable to slide relative to the mounting plate 902 via a sliding mechanism 950. The sliding mechanism 950 will be described in later paragraphs.

A build platform 960 may be attached to one end of the tongue portion 910. The build platform 960 may be an extension at an approximately right angle from the tongue portion 960. Alternatively, build platform 960 may be a

separate part affixed on the tongue portion 910. Build platform 960 is operable to receive fabrication material deposited by the extruder in accordance with instructions provided by a user.

The sliding mechanism 950 platform comprises a plurality of guide points 920, a driving source 930 and a belt 940 connected to the driving source 930 and guide points 920 to effect the sliding mechanism. Driving source 930 is preferably a stepper motor 930. The stepper motor 930 is mounted on the mounting plate 902 and a belt 940 runs through the stepper motor 930. The mounting plate 902 allows the stepper motor to engage the belt and move it in either direction via a pulley system. Both ends of the belt are secured to the tongue portion 910 and by operating the stepper motor 930 in either direction, precise vertical motion of the tongue portion 910 (with a build platform) is achieved. The belt is designed to be hidden behind the tongue portion 910 so a user will not see the belt in operation.

One end of the belt 940 is affixed to a point on the mounting plate 902, and the other end of the belt 940 is affixed to a point on the tongue portion 910. The other parts of the belt 940 ride along the guide points 920 and the stepper motor 930 to form a pulley system.

In normal operation, the sliding mechanism 950 moves from a first position to a second position corresponding to a 'homed' state and an 'extended' state respectively and vice-versa. The 'homed' state corresponds to the non-extended state (see Fig. 9C).

In the 'homed' state, the tongue portion 910 is held upwards against gravity by the stepper motor 930 and the pulley system.

In the 'extended' state (see Fig. 9D), the stepper motor turns in the direction marked E to allow the portion of the belt 940 along guide point 920a and the points affixed onto the tongue portion 910 to lengthen and thereby achieving the maximum length between the build platform 960 and the extruder system 980 of the 3D printer.

In the exemplary usage of four guide points is shown although one skilled in the art can use other combinations and numbers of guide points accordingly.

In further embodiments, the belt can be grooved and a toothed motor pulley can be attached to the stepper motor to engage the belt.

Fig. 9E and Fig. 9F show the side view of the support structure 900 with attached selected components including driving source 930, build platform 960 and the extruder system 980.

In accordance with another embodiment of the present invention there is an apparatus for fabricating three-dimensional objects, preferably via fabrication by layers. The apparatus comprises a housing 1001 for containing the various components including a control unit (not shown for simplicity) for receiving instructions, a cartridge 1020 for storing fabrication material, an extruder 1010 connected to the cartridge to receive the fabrication material and a movable platform 1030 for receiving fabrication material deposited by the extruder 1010. In one particular embodiment, the cartridge 1020 contains the filament and feeds the extruder 1010 via a tube 1025. The control unit can operate the extruder 1010 to deposit fabrication material on the platform 1030. This can be via mounting the extruder to a gantry to move it in the x-direction and y-direction, while the movable platform moves in a z-direction, thereby providing fabrication of a material in three dimensions via additive manufacturing.

The cartridge may be the filament container 14, 820 according to that described in the previous embodiments, which, as illustrated in Fig. 10a and Fig. 10b, will form a regular-shaped cuboid when attached from the top of the 3D printer. The outlet 30, 830 may be positioned along the central axis which feeds to the extruder via a tube known as a Bowden tube. The Bowden tube is a flexible tube which connects the filament entry aperture with the extruder, via the filament exit aperture. One embodiment of the invention uses a component called a fast-interface, commonly used to convey liquids and gases in medical devices. The tube does not flex till its yield point nor does it physically deform and it remains in an elastic region of stress.

The movable support 900 as described in the earlier embodiment may also be adopted in the apparatus of the present embodiment.

It is to be understood that the above embodiments have been provided only by way of exemplification of this invention, and that further modifications and improvements thereto, as would be apparent to persons skilled in the relevant art, are deemed to fall within the broad scope and ambit of the present invention described herein. In particular,

- The filament container 14 itself may be substituted by simply placing filament inside the filament dock 60. This filament then needs to be threaded through the dock's funnel 64 and into the feed mechanism 80. In such instances, the filament (in the form of coil) may be pulled through the funnel assisted by any other rotatable means. The top loading design i.e. loading the cartridge right at the top of printer has the advantage of using gravity to aid the feeding of the filament and in addition achieves a compact regular cuboid design (see Fig. 10).
- While the electromagnet 88 could be omitted, this would disable automatic filament loading. Without the electromagnet 88, the user would have to manually press filament 12 down into the feed mechanism 80 to ensure the drive gear 257 grips it and pulls it through.
- The interaction between the electromagnet 88 and smooth plunger 86 may be achieved via other types of biasing means instead of a spring.
- In another embodiment, a corner feed cartridge 820 is shown in four views without the gimbal attached. It would be possible to use the corner feed cartridge 820 together with a gimbal if so required.

The above is a description of embodiments in accordance with this invention. It is envisioned that those skilled in the art may design alternative embodiment(s) without departing from the scope of the invention as set forth in the followings claims.

The Claims Defining the Invention are as Follows:

1. A filament dispenser for use in a three dimensional fabricator comprising;
a filament container for holding filament material, the filament container comprising an outlet;
5 a filament dock operable to receive filament from the filament container via the outlet;
wherein the filament container is arranged to be disposed within the filament dock;
10 the filament container further rotatable relative to the filament dock such that when filament material is received, the filament container is simultaneously rotated.
2. A filament dispenser according to claim 1, wherein the outlet of the
15 filament container is positioned at the centre of the filament container and the filament dock is operable to receive filament material from the centre of the filament container.
3. A filament dispenser according to claim 1, wherein the outlet of the
20 filament container is positioned off-centre from the centre of the filament container, and the filament dock is operable to receive filament material from the off-centre of the filament container.
4. A filament dispenser according to any one of the preceding claims,
25 wherein the rotation of the filament container disposed within the filament dock is facilitated by ball-bearings.
5. A filament dispenser according to any one of the preceding claims,
30 wherein at least one gimbal is positioned proximal the outlet.

6. A filament dispenser according to any one of the preceding claims, wherein the receiving of filament material is automated with the aid of an electromagnetic circuit.

5 7. A support for use in a three dimensional fabricator comprising;
a mounting plate for an extruder to be attached thereon; and
a tongue portion operable to slide with respect to the mounting plate; the
tongue portion operably connected to a build platform;
wherein in operation, the distance between the build platform and the
10 extruder is slidably adjustable between a first position and a second
position; the first position corresponds to a default start state and the
second position corresponds to an extended state.

15 8. A support according to claim 7, wherein the build platform is integrally
moulded with the tongue portion.

9. A three dimensional fabricator for fabricating objects comprising:-
a housing;
a control unit for receiving instructions from a user;
20 a filament dispenser according to any of claims 1 to 6;
an extruder operably connected to the filament dispenser to receive
filament material for fabrication;
a support according to claim 7 or 8; the support comprising the
movable platform for receiving filament material deposited by said extruder;
25 wherein the control unit operates the extruder and the movable
platform to deposit fabrication material on the platform in a pattern according
to received instructions.