Disposable Dispenser-Cum-Extruder Units for 3D Printers to Use with Wet Mix Materials

Dr. K. Kamal, FIEI, FIIBE, FAIstructE
C/o CED, Ajay Kumar Garg Engineering College
27 Kmstone, Delhi-Meerut Expressway, Ghaziabad UP 201009 India
drkkamal.jss@gmail.com

Abstract -- **Some unique, dispenser-cum-extruder units that easily get fitted-in any FDM based commercially available 3D printers, replacing the already provided therein the semi-liquid polymer filament wire extruder units were successfully created and also effectively used. Development process of all the components of these 3D printed hardware of dispenser-cum-extruder units involved a very low cost, recyclable material; therefore these may be disposed off even after their one-time use. These dispenser-cum-extruder units, when attached to any FDM based 3D printers, offered to effect a provision to toggle, on need basis, between the use of the required types of extruder units. Thereby, all these printers can as well create some objects in wet mix materials, that are deployed by the construction industry, turning these 3D printers therefore, into the dual-technologies used modern tools.**

Keywords: 3D printers, Wet Mix Materials, Additive Manufacturing, Slicing algorithm, Dispenser-cum-extruder

I. INTRODUCTION

DISPENSER-cum-extruder units that are created and as has been detailed hereunder, are the assembly comprising of all those various hardware components which are 3D printed out in PLA materials, utilizing the three dimensional controlled movements which are built in any FDM based 3D printers commercially available for rapid prototyping. Owing to these 3D printed out components in comparatively inexpensive materials, and designed to facilitate their easy mounting with possible interchangeability, these dispenser-cum-extruder units can be easily removed and disposed off and body material extracted for possible recycling. It is found that these units on deployment for having used with any paste like cementecious materials, work well further for dispensing any powder form of construction materials too, as these are sprayed through the suitably designed nozzles attached at the end, in a controlled condition, layer-by-layer, over an already laid wet layer and hence the desired 3D solid objects get printed out successfully.

The design and development of dispenser-cum-extruder units involves three basic steps. The first step consists of creating 3D software models of their various individual parts on the computer, assembling, each of them on computer and conduct simulation study on computer screen itself. Details of this effort of software modeling and also the computer function simulation study, have already been reported by the author [1]. As may be seen, this step ensures the dimensional accuracy prior to actually getting hardware of these components 3D printed. In the next step, an in-house fabricated and already patented 3D printer [2] was employed. The third step involved was these extruder units mounted in-place over 3D printer and successfully carried out 3D printing process, demonstrating the use of wet construction material.

During this study, it was experienced that the walls and the nozzle of the units got generally clogged after each printing process, as materials that passed through them got hardened inside. It was realized that any similar units in metal for example, if used, would have certainly faced the same situation and therefore needed a thorough cleaning to ensure their effective reuse. All this means to adopt tedious and time consuming off-line process, that may interrupt the continuing of the 3D printing process.

From the study conducted, using these created hardware built-in a very low cost material and also having effective mount and anchor holders, found to offer time saving and also facilitated the near continued printing of the 3D objects. The entire extruder unit here can be easily fitted / removed and disposed off after their one time use. Further, polymer material so used in the body of these printed hardware components, may also be extracted back and recycled into wires for reuse, for example, again in printing similar new units on the same FDM based 3D printers.

II. RAPID PROTOTYPING

Rapid Prototyping (RP) has been one of the effective tools that are widely adopted by many engineering Industries, used in iterative design and inspection, to create quality prototypes. Most used method of this RP that is found further reported in the literature being the traditional machining which, as used, did undergo continuous advancement with time. With the advent of computer-aided-design (CAD) /computer aided manufacturing (CAM) workflow, CNC subtractive manufacturing has come into existence. It was further learnt that, on merely following the simple invert process only, the same rolled out as, now popular, Additive Manufacturing (AM). Till very recently, this AM technology was looked upon as might not be able to process those materials, possessing higher mechanical and physical properties, as used as the construction industries, essential requirement.

With ushering of digital era and huge digital modeling data handling possibility, use of this AM technologies have also got however re-defined, by which, it started offering, ease in production of any engineering objects, with adequate mechanical strength properties, suiting any application environment and also processing, with any customized mix materials that includes ceramics and metals paste as an alternative to process, only with that widely used polymers. Researchers are working the world-over, to adopt AM technique that can handle even the laser aided molten glasses and hence may create huge glass objects and buildings of complex shapes as well in future.

Efforts are also found as currently on to identify and resolve those various design and operational issues faced in adopting 3D printers for construction in it's materials. Using AM technologies, since, any shapes can uniquely be generated layer-by-layer without incurring prohibitive costs on required moulds and formworks in construction works, growing interest in the construction industry may therefore also be seen in adopting such AM technologies. It has been possible now to suitably design the mix of construction materials and handle them in the form of, either wet paste mix or, in the form of dry powders.

The requirement that remained still vital has been to select a suitably designed dispenser-cum-extrusion unit, that may be fitted in any commercially available 3D printers with ease and produce 3D objects or structural components for construction applications. Once identified, the proper cementations mix, and also developed successfully the required effective dispenser-cum-extruder unit, it is felt that the commercially available FDM based 3D printers themselves (preferably a scaled-up version as in fig. 1*a*) may become one of the most modern construction tools for site in various 3D print out elements that are as used by the construction Industry.

III. 3D-PRINTERS THAT TURN INTO DUAL TECHNOLOGIES USED MODERN TOOLS

In 3D printing of any object, the process requires software and once such software is installed on an electronic device, a solid model is subsequently created then. The CAD model so created is first converted on the computer into a required standard format file, such as Stereo-lithographic file (.STL file), a Virtual Reality Modeling Language (VRML) file, etc. This file represents a part of the surface of the 3D model which is then used for implementing slicing algorithm. This file of the 3D model, now consists of a mesh or series of triangles, oriented in space that encloses the 3D volume. The file has slices of the model into thin cross-sectional layers based on which materials layers are laid to print the 3D objects. Therefore, a 3D Printer, that is employed in this study that is covering the developmental works as reported here, was also a software aided system that has been designed as a compact 3D printer, by forming a light weight modular assembly so as to permit its easy assembly and dissemble it, at the site. The process of 3D printing requires a positioning system, as being CoreXY, in which, the required motion is driven by two stationary stepper motors driving the belt and hence, offer enhance dimensional accuracy of these printers. The controller is electrically or otherwise coupled in a communicating relationship with the driving mechanism of the x-gentry, the extruder assembly, as well as, other components of this 3D printer.

In general, the controller is operable to control all the movable components of this printer that prints the 3D objects. The extruder assembly mounted, using an anchor holder, disposes out /extrudes the material that flow from top end over the movable x-y frame, within the enclosed area enclosed by the outer frame of this 3D printer. As shown in Fig. 1*b*, this anchor holder moves along with the moving x-gentry over x-y frame, for which, it is provided with two linear blocks and two rails respectively, each mounted on either side members of its supporting frame, that allow the smooth movement of x-y frame and the anchor holder. The extruder unit here is fairly a lightweight assembly and hence, it significantly reduces the motor power required for its movement, thereby rendering the cost effective printing of any 3D objects. Here, the moving x-gentry may be mounted with two types of extruder assemblies for use of different materials to be extruded, such as one FDM based polymer filament extruder and other as, the wet mix material extruder to print out 3D objects specially for construction applications. Once the 3D software file is generated, the 3D printer is switched on, the controller activates the selected extruder assembly, the stepper motors, the gear and all the pulley systems. The extruder assembly is then moved along the X and/or Y axis and lays a first layer of any identified 3D objects. Nozzle of this extruder assembly, dispenses the material mix onto the base of its outer frame initially, and then as per the movement of the extruder assembly, layer by layer. Post the formation of the first layer, controller activates the stepper motors to move upwards along the Z-axis, lowering the counter weights hanging on either sides. Thereafter, these steps are repeated, that lays a second layer over the first layer and the process is repeated till the complete 3D object is created. Finally, the 3D objects so printed out in the construction mix on 3D printer, optionally may undergo plastering, lacquering, painting, etc as usual.

An architecture of an scaled up version of such a 3D printer, includes a plurality of support members which are connected together forming a stiff and sturdy outer frame, as shown in Fig. 1*a*. For a durable support as required, the members used here are only profile of aluminum T slot angle extrusions. A rectangular x-y frame, moveable in z-direction within this outer frame, carries an extruder assembly and a controller, mounted over an x- moving gentry, is as shown in Fig. 1*b*. All these components of this 3D printer, operate in a synchronized manner and thus, print out, the required 3D object. An enclosure to this outer frame may also be provided, which consists of a plurality of walls, that forms a rectangular box structure. This enclosure fully encloses various components of this 3D printer and may be made up of some durable material such as metal or polymer/acrylic sheets. This enclosure box offers the impact resistant, therefore, it provides all, within it, the required safety during printing of 3D object that are being printed out by this printer, along with its supporting frame. A wall of this enclosure also includes a transparent glass window portion, needed for the user to visualize/monitor formation of 3D objects within this enclosured frame.

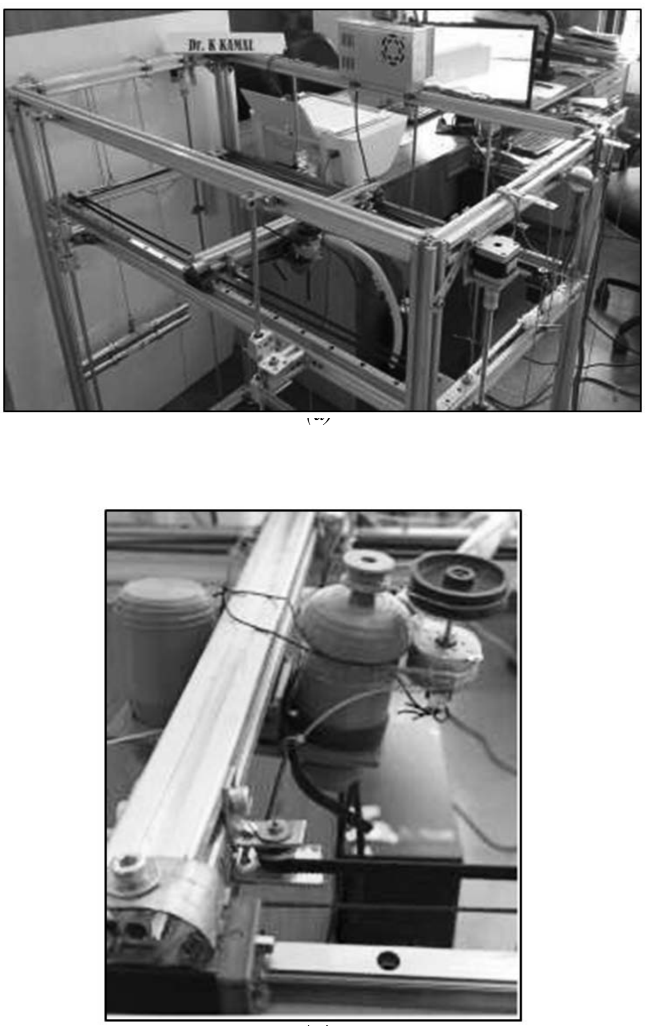


Figure 1 (*a*) View of the outer frame architecture in a 3D Printer (*b*) Dispenser in place.

The movable x-axis gentry, made of aluminum profile, along with its x-y frame as support, carries the extruder assembly, on a mounting anchor, is positioned in z-direction close to the base initially. On either side of the outer frame, two counterweights are attached to this movable x-y frame through cables, hanging from four numbers of mounted pulleys, each two respectively at top of the side members of this supporting frame. Such an arrangement, assists the driving mechanisms to operate with ease and hence requires low powers. Two threaded rods act as vertical lead screws to help the x-y frame to move laterally (up and down) along with gentry, holding the Dispenser cum Extruder unit, slide in z-direction while the counterweights attached to it move laterally in reverse, along the vertical support members of its outer frame. Here, each threaded rod is coupled to a driving mechanism, being stationary stepper motor whereas the vertical support members act as guide for the x-y frame and x-gentry to move upward smoothly. The x-y frame and x-gentry are moved along the Z axis over these threaded rods by two stepper motors controlled by the positioning system. The aforesaid movement of the extruder assembly and the gentry in x-y plane is mediated here by CoreXY. The CoreXY mediated motion of the extruder assembly and/or the gentry enhances the accuracy of the printing process. The extruder assembly of this 3D printer is so configured to move along X axis and Y axis with the help of two stationary stepper motors on each side of the x-y frame. The stepper motors operate in tandem to reach a particular position having a predefined X and Y coordinates. The dispenser-cum-extruders therefore, is made movable here in one or more of the X, Y, and Z axes and hence lay the printing material and form the 3D object. The movement of the extruder assembly when commences the dispensing of the mix on the base, results in formation of a first layer of the proposed 3D object to print. Once, the first layer is laid over the base at bottom of this printer, the x-y frame and gentry move upwards equal to layer thickness and this process is repeated till each layer is laid.

IV. FEATURES OF 3D PRINTED DISPENSER-CUM-EXTRUDER HARDWARE UNITS

To facilitate adoption of available FDM based 3D printers by the construction Industry, a suitable design mix dispenser-cum-extruder unit was required, that has been drawn on the CAD software first and then created those various components hardware by printing out each of them through a printer which was of the type of commercially available 3D printers [2], identically as described above in the preceding para. The entire effort covered in this exercise and study, began with designing this dispenser-cum-extrusion unit by generating the 3D model, part by part and then, assembled them (as shown in figure 2) in ‘CREO’ software, where, simulated all functions, the study of which, have already been reported in the literature [1]. These dispenser-cum-extruder units, consisted of three main components, namely (*i*) the mix tank, (*ii*) pumping mechanism within and (*iii*) the printing nozzle.

Here, the wet material mix starts its journey at the tank(mixer) and it is then pumped out through the dispenser unit by an

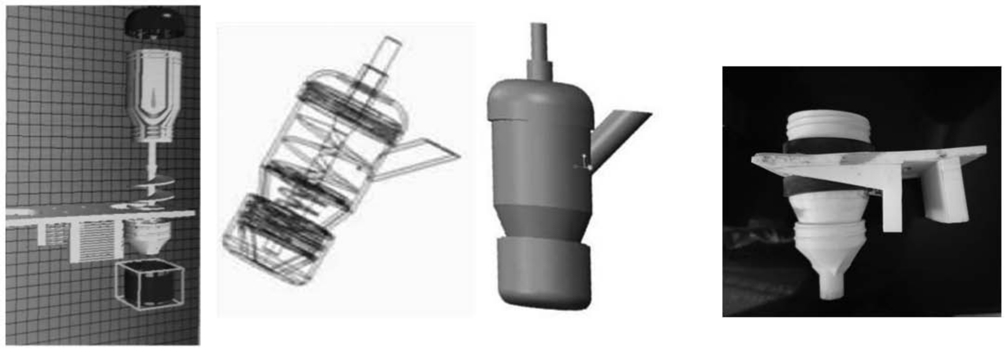


Figure 2. Required holder to suitably fit Extruder assembly to moving x-gentry of a 3D printer.

auger pump to reach it to the nozzle, being responsible for a controlled extrusion of the mix material. 3D printer on which this unit is attached uses movements in the x-y-z, (tri-axial) plane to dispense this material mix and thus prints out some 3dimensional elements in such material mixes [3]. The dispensing system is anchored with a suitable holder which also has been designed and 3D printed out, that facilitate easy fitting to the printer as an alternate unit to that extruder unit for polymers/PLA wires which comes along with any such FDM based 3D printers, those can be seen as widely in use for mechanical and other engineering applications.

These printers, thereby, are now made for their extended use in various applications in the construction Industry. The dispenser-cum-extruder is provided with an interchangeable nozzle feature, that as well allows choosing type of nozzle according to the requirement of extrusion material strips in desired shapes and sizes, with or without interlocking for the layers.

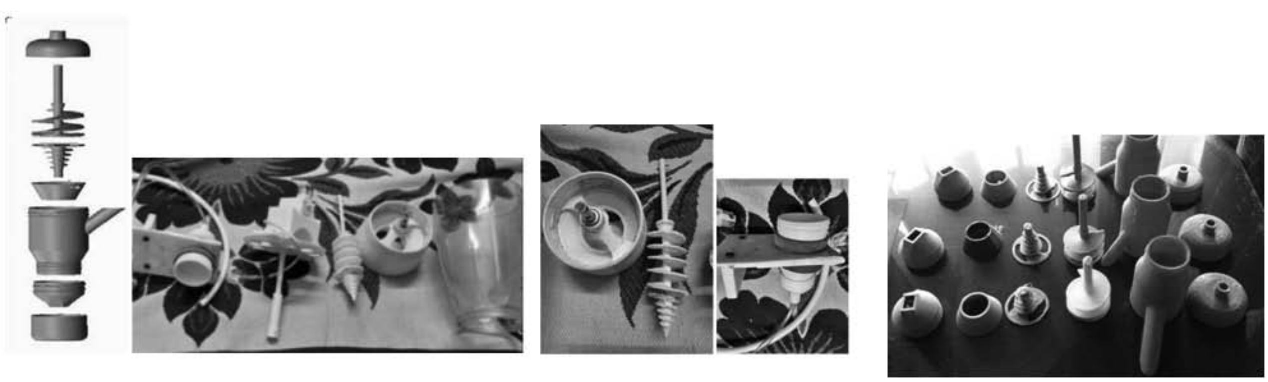
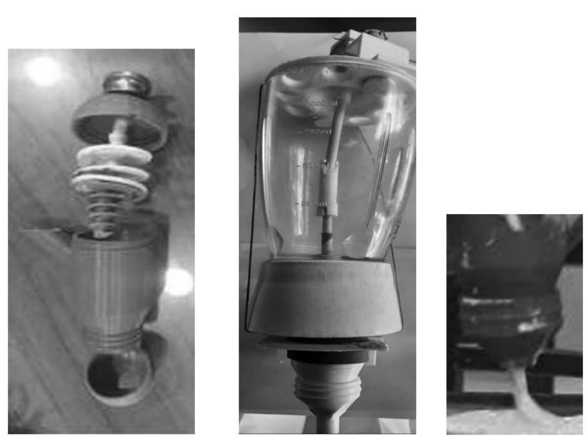


Figure 3. Dispenser-cum-extrusion unit before assembly, depicting all component hardware.



(*a*) Component & Hardware (*b*) Attached to Mixer (*c*) Extrusion demo of wet mix

Figure 4. Hardware of dispenser-cum-extruder unit, 3D printed out in PLA.

All the components of this dispenser-cum-extruder unit (shown in figure 3) are made out of low-cost material and each can be 3D printed out in no time, through FDM technology based, extruder unit comes for PLA wires in the 3D printers. Figures 2 to 4 may be seen above for all those various hardware components of this so created unique Dispenser-cum-Extruder. In this, the dispenser shaft having a pulley at its top, is driven by a belt, that may be coupled to rotate by an stepper motor, attached to the mixer cylinder's top cover as shown in Fig. 4*b*. Giving the required motion in the desired direction to an auger that is fitted at the lower end of the shaft, a continuous supply of the mix material is ensured into a rotating, twisted blade of an auger, that aids proper supply of material mix to flow, till its end where an extrusion nozzle is provided. This extruder assembly, slides into an anchor holder, that is fitted and moves along the X-axis onto x- gentry and this extruder assembly unit also, slides together with the x-axis genty movement, over x-y axis frame. All these x-y frame movement and the extruder assembly are driven by a driving mechanism as two stationary stepper motors mounted on the x-y axis frame itself, mediated by CoreXY.Movement of extruder assembly and/or the x-gentry occurs in such position, only when directed by a computer with which the electronic device of 3D printer is in communication (either wired or wirelessly). This electronic device is installed with software, thus it directs the movements as per digital model of the object generated and hence, 3D object is printed out. The digital model here is a 3D information file describing the 3D printable object in three dimensions, the details of the 3D object to be laid, for example, the dimensions of the object is initially fed manually to the electronic device, before the hardware printing is initiated.

V. CONCLUSION

Wet materials Mixer attached to a Dispenser-cum-Extruder units are suitably designed now with Hardware components as have all been actually 3D printed out, using an in-house developed and now, commercially available FDM based 3D Printer. The assembly of these components into a functional hardware unit, when fitted, replacing the existing extrusion units used in the printer for semi liquid type polymers, facilitates with an option to print, any 3D objects in various wet mix material as well. A scaled up printer, similar to this commercially available FDM based 3D printer, was in-house developed and due to such option to choose the type of extruders on need basis, provided therein, found to allow toggling between the use of two types of extruder units. This option became feasible, only when deployed these new units on to 3D printer [4] and become workable with materials such as PoP or cement mortar as well and hence turned out now as the dual technologies used modern tools for any engineering applications.

VI. ACKNOWLEDGEMENT

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REFERENCES

[1] K Kamal, Ms Afsa, and Ms Medhavi Kamran, 'Design and development of an extruder unit, Generated through modelling its parts, assembled and simulated for use in 3DCP', *International Journal of Applied Engineering Research*, vol. 13, no. 9, pp. 1-4, 2018.

[2] '*Three Dimensional Printer*', Patent No. 344163 Granted on 8-10-2018 to AKGEC skill Foundation, Adhyatmik Nagar, Ghaziabad 201009 UP India

[3] K. Kamal and P. Tiwari, '3D construction mix printer (3DCMP) fitted with a disposable, dispenser cum extruder unit' Construction Management tools in built environment', *Journal of IBC*, vol. 27, no. 1, pp. 43-47, 2019 (received the Best paper Award).

[4] K. Kamal, '*Human portable light weight, foldable 3D construction mix printer*', Patent filed and published in *The Journal of IPO*, dated 29/07/2022.

Prof. K. Kamal is graduate in Civil Engineering and post graduation in Structural Engineering, started his service to Nation with teaching under graduate classes in Civil Engineering and then at the Applied Mechanics Division of a MN Regional Engineering College (now NIT), Allahabad.

He obtained his doctorate degree in Structural Engineering from Indian Institute of Science (IISc), Bangalore, India. In 1984 he taught under graduate as well as post graduate classes of construction technology in Civil Engineering Department of BMS College of Engineering, Bangalore. He worked on prestigious LCA /Tejas project of MoD, Govt. of India and subsequently, as Head Composite Research Centre for DRDO at R&DE(E), Pune where he executed several Advanced Composite Products Design & Development projects for Civil Engineering as well as a few for IGMDP applications.

He was then Director (TUD) in 1995 and then became Adviser, DSIR, MoST, GoI. Subsequent to his superannuation form GoI, he re-joined to serve academics as Professor of Civil engineering. He worked respectively at JSSATE Noida and AKGEC under AKTU and JSSATE Bangalore under VTU. During this, he has been as Principal, JSSATE Noida for two years and then also contributed for an year as Dean (R&D) & HoD (Civil), at AKGEC. He is an active Fellow /life member of over 15 professional bodies. As President's Rover Scout, he is a recipient of Fellowship Gold Medal of BSG-India as encouragement to his service to living kinds. He has been honoured with Life Time Achievement Award by IJIEMR-Elsevier SSRN, 2022.