The concept of Viscous Material (Chocolate) 3D Printer/ Food 3D Printer

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Abstract - *In this research paper, discussion is done on 3D printing technology which is a newly developed manufacturing technology. In this paper, explanation of the concept of 3D printing technology along with its importance is done. This paper lists the application of 3D Printing technology using some viscous material to prepare various objects as well. Preparation of objects from a range of viscous materials like chocolate, concrete, cement, silicone, clay, ceramics or wax using a 3D printer can be achieved by developing a 3D printer with syringe extruder mechanism. This concept aims at utilization of 3D printing to make objects which are not as irrelevant and useless as PLA or ABS objects, but can be intended for use in confectionary industry or construction field by generating personalized objects having intricate and complex detailed shapes. For now, we have primarily focused our attention on chocolate printing. The chocolate 3D printing is similar to pushing of chocolate through a syringe by a chef. The advantage it poses over the manual process is repeatability and accuracy cum precision of detailing. To print any desired shape, we need to design the object on CAD software, and then export it in STL format followed by generation of G-code and uploading it to the printer firmware. At last, the applications, future, scope of viscous material 3D printing technology is elaborated.*

Key Words: Chocolate 3D printer, Wax 3D printer, Concrete 3D printer, 3D printing, syringe extruder, Additive manufacturing, Confectionary industry, Food Printer

1.INTRODUCTION

3D Printing is technology is used to manufacture the various parts in 3D Shape[13]. It uses a layer by layer procedure to form the complete shape of the object. Commonly, plastic is used for 3D Printing but we have used some viscous material to print the various objects. This research paper involves the various design challenges[18] and issues we faced prior to the successful trial of the 3D printer, its features, advantages, disadvantages and future scope. We have modified the existing mechanism of 3D printers, making it possible to print various viscous materials such as chocolate, fine concrete, cement and wax. In this paper, we have focussed our attention on 3D prints using chocolate as material and issues faced towards its development. 3D Chocolate Printing is an additive manufacturing procedure of generating three dimensional solid chocolate objects from a digital design. The creation of 3D printed[2] chocolate follows the principle of additive process, which is creating the entire chocolate object by laying down multiple and successive layers[1] of chocolate through the nozzle of the syringe fed extruder. This process of laying down chocolate layers is continued until the entire object is formed. These layers may be visible in the final product in the form of thinly sliced horizontal cross-sections of the final product. 3D printing is advantageous over the conventional manufacturing processes as additive processes use comparatively lesser amounts of material.

1.1 Features of Chocolate Printer

The primary object behind developing a chocolate based 3D printer is to cater the need for generation of personalised items according to an individual's demand and needs. It allows for production of fancy items which might not be possible to make economically using conventional chocolate mounding process on a small scale. The unique advantage of chocolate 3D printer is that every item printed from the printer can be completely different from other item. The consumers can design their unique item and eventually take it as a special souvenir. Moreover, the chocolate coming out from a 3D printer is ready for consumption and does not need to undergo any further refinement or treatment process.

Intricate and complex shapes of chocolate which are not feasible to be made using chocolate mould can be easily produced by a 3D printer after following the prescribed set of procedure. Due to prevention of repeated mould and pattern making process, the cost of operation is comparatively lower than the conventional and traditional process of chocolate making using moulds. The G-Code controlled movement of the extruder gives higher degree of accuracy, precision and repeatability as compared to manual extrusion process. This eliminates any chances of error in the movement of the extruder on the prescribed trajectory. Moreover, the operation speed is much faster than any other process involved in creating similar complex chocolate designs.

1.2 Technical Specifications

The optimum printing conditions included a printing speed of 5 mm/sec, nozzle temperature of 40 C, with nozzle diameter varying from 0.75 mm to 3 mm and layer height depending on the nozzle diameter[10, 11, 12]. The operation time may vary and will depend on the volume of the chocolate to be extruded out of the printer for printing. The nozzle diameter can be varied according to the requirement for size and accuracy required for print (small diameter for small sized accurate prints and bigger diameter for larger prints).

1.3 Procedure of Operation

1. Decide what is needed to be printed.
2. Create a 3D design of the idea on CAD software.
3. Export the design in STL format.
4. Feed the STL file to slicing software like Cura which will generate a G-Code.
5. Upload the G-Code to printer board using communication software such as Repetier Host.
6. Prepare the raw chocolate in required composition, set the printer on pre-heat and start the peltier cooling mechanism.
7. Melt the chocolate externally and fill the syringe with molten chocolate.
8. Insert the syringe into the printer and start the printing operation.
9. Manually press the Z-axis mechanical end stop switch whenever required.
10. Control the feed speed and printing speed to meet your requirement from the LCD panel.
11. Prepare a second syringe, in case, the existing syringe runs out of chocolate.

2. PARTS AND MECHANISMS INVOLVED

The various parts and mechanisms terminologies required to understand the operation of the printer are discussed.

2.1 Extrusion via Syringe

The printing head of the chocolate 3D printer is in the form of a syringe. The top of syringe plunger is in contact with the pushing mechanism. The pushing mechanism is driven by a Nema-17 stepper motor programmed[17] as extruder motor in the firmware[16]. The pushing mechanism serves the purpose of conversion of rotatory movement of stepper motor to vertical movement of plunger by utilising an assembly of mechanical elements. This assembly consists of a secondary gear driven by stepper motor gear and supported on roller and ball bearings for smooth rotation. The centre of secondary gear houses a hexagonal nut which rotates with the gear. A threaded rod passes through the nut. The entire gear, bearing, nut assembly is fixed between two horizontal rails which prevent vertical movement of nut upon its rotation. As a result of restriction of rotation of the nut in vertical direction, the threaded rod is pushed downwards. To one end of threaded rod, is attached a slider which comes in contact with the top of plunger and pushes it downwards. The vertical movement of the syringe plunger creates pressure in the syringe which forces the chocolate out through the nozzle. The vertical push experienced by plunger is in proportion to the rotations per minute of the stepper motor. This speed can be controlled via the firmware to increase or decrease the pressure in the syringe and hence, the flow of chocolate from the nozzle.

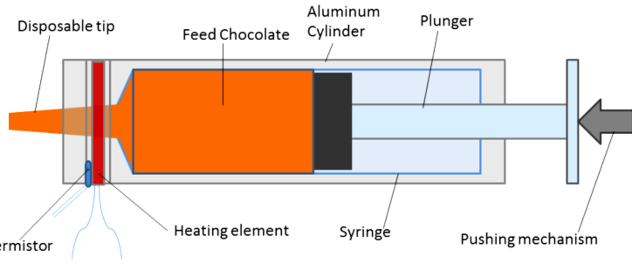

Fig -1: Extrusion and Heating Mechanism

2.2 Heating Mechanism

The syringe is enclosed in an aluminium cylindrical body. Aluminium is the best suited material due to its thermal properties. This cylinder ensures uniform heating of the material and may prevent formation of any lumps. The height of cylinder is kept the same as height of syringe to heat up the entire syringe. This cylindrical entity has a hollow cavity at its bottom which houses the heating coil and thermistor. The thermistor is responsible for sensing the temperature at the contact surface of the aluminium cylinder and communicating the data with the printer firmware. The heating coil used utilises the principle of resistance heating and may operate at voltage of 12V while consuming 40W to give optimum output. The coil is capable of heating up to temperature ranges of 180-200 C. The operational temperature may be given input to the firmware of the software and may depend on the melting temperature of the substance used in 3D printing. Higher ranges of temperatures may be used with materials such as silicone. Paste based materials may not require heating of material and heating coil may be rendered non-operational. Insulating layers in the form of Kapton tape may be provided over the cylinder surface to prevent any heat loss to the surroundings and to maintain same temperature throughout the syringe material.

Fig -1: Kapton tape for insulation

2.3 Peltier refrigeration

When a certain value of current is passed through the peltier cells, a temperature difference is generated amongst the two sides of the peltier cell, with one side having temperature higher than the atmospheric temperature and other side having lower temperatures. To obtain cooling effect, the hotter side is bought in contact with heat sink where fans dissipate the heat generated by the cells and the cooled side is fitted at the bottom of the bed of the printer. Aluminium is used as material for construction of the bed due to its thermal properties. The cooler side of the peltier cells is bought in contact with the metal bed so as to obtain a cooling effect[15] at the bed which will aid in the solidification of the material printed out of the extruder. An additional cooling assembly consisting of fans, ice gel packs, etc. may also be used, focusing on quicker solidification of the object printed.[15]

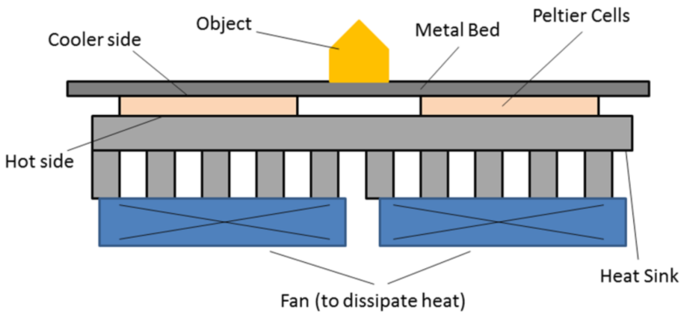

Fig -3: Peltier cooling mechanism

2.4 LCD Panel

The LCD Panel acts as a info screen along with controls for speed, temperature, pre-heat, etc. It is based on Arduino and consists of a SD card slot to feed the G-Codes to printer, a display LCD and a Control knob.

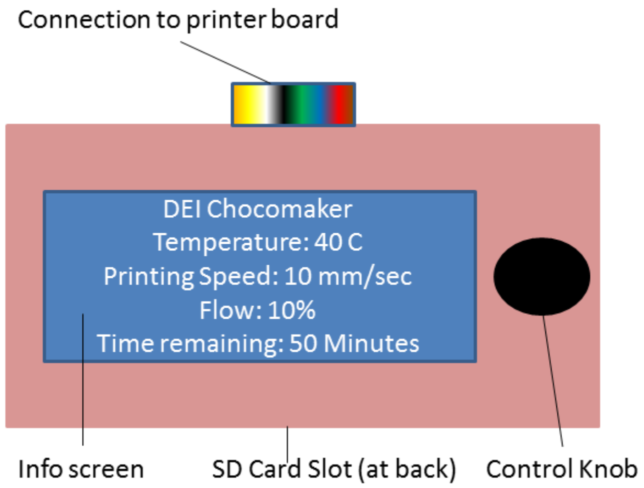

Fig -4: LCD Panel

3. ADVANTAGES OF CHOCOLATE 3D PRINTER OVER CONVENTIONAL CHOCOLATE MOULDS

Chocolate is extremely difficult to work[19] with, and presented a lot of a challenge to the team. However, after considerable research and testing, we somehow managed to achieve it. These challenges include the following.

3.1 Personalisation

Adequate Chocolate moulds are not suitable for personalised and customised orders of customers. There is a limitation in the availability of the various shapes of chocolate mould. However, 3D printer is the perfect solution for the customised orders as almost anything can be designed on CAD[4,5] software and fed to the printer.

A single mould can be used to prepare chocolate of one shape only. But the output from a printer can be of varying and different shape every time, depending on the file input. Thus, 3D chocolate printer provided flexibility.

3.2 Economic Advantages

The chocolate moulds used to give shape to the chocolate in traditional processes could be made of polycarbonate materials or Polymers. The overall process of creating various different shapes of chocolate using moulds may prove more expensive than the 3D printing operation.

Any improvement in the design of the object[3] may render an existing mould useless. Moulds have to be redesigned and require to be made again with any subtle change in design. In case of chocolate 3D printer, the changes can be easily incorporated in the 3D design fed to the printer.

A chocolate mould for intricate design and made of polycarbonate material or Polymers[8] may cost anywhere between 1000-3000 INR. As an alternative, the chocolate 3D printer is a single time investment and does not require frequent purchase of moulds with change in design of chocolate.

3.3 Small Quantity Orders

Chocolate moulds are widely used in chocolate and similar confectionary industries where chocolate is produced in bulk quantities (quantity more than 100). These chocolate moulds are not suitable[14] and ideal for small quantity orders where only a few pieces are to be made on individual levels. In such case, the high initial investment cost of moulds renders it uneconomical and unfeasible where large profit is not guaranteed, owing to the low volume of production. The moulds may also be left useless upon completion of production. So, chocolate 3D printer (being a onetime investment and could be used later as well for a different design) is the best suited option for production of one type of design at a small scale.

3.4 Quality of chocolate

Improper temperature and viscosity control of chocolate in moulds may lead to presence of air in the chocolate which will form bubbles in the chocolate. This is not the case with 3D printed chocolate because the chocolate is formed layer by layer and is not dumped all at once.

3.5 Better temperature control

Conventional chocolate making process carried out using moulds may require additional devices for measuring, maintaining and controlling temperature and other physical aspects of chocolate. A chocolate 3D printer has a thermistor incorporated in the extruder which helps in accurate control of temperature and firmware maintains the temperature and prevents any rapid fluctuations in it.

3.6 Better viscosity control

The extruder hole opening prevents viscosity of chocolate syrup from being too high or low. Highly viscous chocolate will not be able to pass from smaller opening hole on the extruder. Any nozzle diameter can be obtained by suitable machining of the plastic nozzle attached to extruder opening.

3.7 Ease of removal of chocolate

Chocolate made by moulding often remains sticked to the mould and makes it difficult to release it from the mould. This situation may have arisen due to mould being either too hot or too cold (inaccurate temperature control). In the case of 3D printer, there is no such situation requiring removal of chocolate from any cavity as it is directly placed in its finished form on printer bed.

4. DISADVANTAGES

Not suitable for mass production of same design: Owing to its small speed, 3D printing is not suitable for mass production of identical bars of chocolates having basic simple size and shapes.

5. CONCLUSIONS

Inclusion of viscous materials to 3D printing technology will create a boom in the related industries. Owing to its very few disadvantages when compared to the numerous advantages it offers, viscous material 3D printing can be considered a very effective fabrication technology. If properly developed and researched upon, the viscous material 3D printing technology is expected to replace the conventional methods of manufacturing. Development process of related machines might be a cumbersome and tiring process, but it guarantees impressive returns

ACKNOWLEDGEMENT

We would like to express our gratitude towards Prof. P.K. Kalra (Director, Dayalbagh Educational Institute) who allowed us to utilise the 3D printing labs and facilities of the institute. We acknowledge the efforts and hard work by the experts who have contributed towards development of this project. We take this opportunity to express our profound gratitude and deep regards towards Prof. Soami Pyara Satsangee (Incharge, USIC, Dayalbagh Educational Institute) and Hardik Chadda (Director, Hankernest Technologies) for their exemplary guidance, monitoring and constant encouragement throughout the course of development of this project.

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BIOGRAPHIES

Rajeev Satsangi
He has been a lecturer in DEI Technical College since 2009. He has been teaching Hydraulics & Hydraulic Machines, Manufacturing Process, Metrology and Measuring Instruments, Elementary Mathematics. His Research interests are Alternative Thermal Systems, Novel Manufacturing Technology and Consciousness. He has published his research findings in International/ National Conferences. He attended STC in NITTR, Chandigarh. He is also a Life Member of Systems Society of India. His knowledge of manufacturing process proved fruitful in the research process.

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Born on 29th June 1997, he is a final year student of Diploma in Mechanical engineering. He was introduced to the concept of 3D printing in Winter Camp (December, 2016) at Dayalbagh Educational Institute. He acquired knowledge of working of 3D printers and related concepts during his internship at Hankernest Technologies (June 2017). His key areas of strength include Computer Aided Designing, Machine Design, Basic Electronics, Manufacturing Process, Refrigeration and Air Conditioning, Thermal Engineering. He has an analytical mind and is committed to his research. His systematic approach, innovative ideas, knowledge, problem solving skills and dedication were key contributing factors towards competition of this machine.

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