3D PRINTING HEAD TO PRINT WITH VISCOUS MATERIALS PROJECT

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Abstract
The article is analyzing possibilities to design and use 3D printing head which would have an ability to print with viscous materials. Possibilities to regulate debit of ejected viscous material with pressure or by volume methods are analyzed.
Research includes analysis designs of known 3D printing heads to print with viscous materials; review of their advantages and difficulties to use. Experimental research on specially produced laboratory equipment and designed 3D printing heads are presented. Main tests were done using liquid ceramics.
Viscoelasticity of ejected material, printing and material flow velocity are main parameters possible to variate to get quality prints. Very big attention to drying process of ejected material needs to be paid.
Key words: *3D printing, 3D printing head, viscous materials*

Introduction

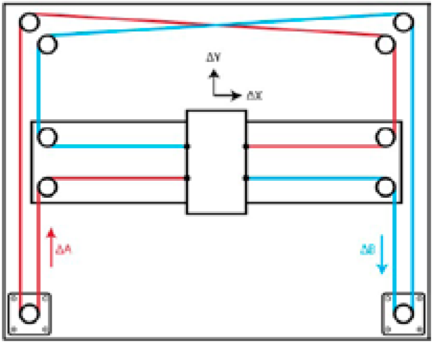
Nowadays technologies of 3D printing are rising in high speed with its innovative ways to bring new and exotic printing materials. That way 3D printing head to print with viscous materials project was picked as press engineer study program's bachelor final thesis.

Analysis of known 3D printing heads to print with viscous materials, their advantages and weakness leads to decision to use progressive cavity pump principle (moineau in short). Such design transfers fluid by means of the progress, through the pump, of a sequence of small, fixed shape, discrete cavities, as its rotor is turned. So, it leads to the volumetric flow rate (volume of fluid passes per unit time) being proportional to the rotation rate. This method gives an ability to control fixed amount of material through nozzle.

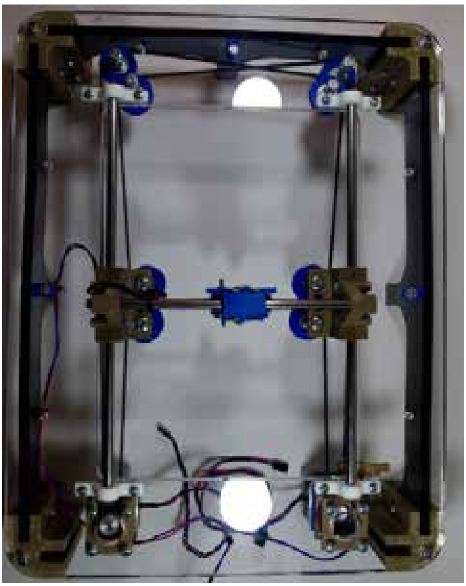
White clay was chose as the main material to test printing head, analyse its problems and flow-rate configurations. Clay is known for its difficultness to mold and make correct viscosity.

Testing board

In order to test such printing head, it was required to build head moving machine. Built plotter is based on CoreXY principle (1. Fig.). Important to note that this principle is superior comparing to other mechanical arrangement because of required lower inertia. In other words, gives more rapid acceleration. Another notable thing is low price of components.



1. Figure. CoreXY principle.[1]



2. Figure. Built CoreXY board.

This testing board (2. Fig.) is controlled by “Arduino” microcontroller board. It’s installed with open-sourced “Marlin” firmware with minor changes to adapt this system, receives “G-Code” command lines which is created by slicing program and firmware interprets into movements and other commands.

3D printing head

Progressive cavity pump principle can be implanted into lot of technologies and one of them is 3D printing head to print viscous materials. Most of current heads are structured with screw/ auger technologies to control flow rate and that makes cavity pump a new approach into 3D printing technology. Strong sides of this design are ability to control same volumetric extrusion despite of material’s viscosity, rotor and stator are maintained for a longer period comparing to auger/screw designs.

“Moineau” extruder is made from few different parts and assembled together for printing use (3. Fig.) and could be easily disassembled for cleaning or changing parts. These parts are printed with 3D printer in ABS plastic.

3. Figure. Parts of progressive cavity pump’s extruder.

Short review of main parts:

1. Rotor. It takes a form similar to corkscrew and makes off-center movement.
2. Stator. Designed to fit rotor inside and is formed set of fixed cavities in between.
3. Universal joint. Solution used because of rotor off-center movement and powered by stepper motor.
4. Material inlet tank. Receives materials from outside tank and moves into stator when rotor is moved. Also universal joint and motor is connected via shaft inside inlet tank.

5. Nozzle. Could be designed with various diameter by need, mainly 1–3 millimeters.

6. Stepper motor. Moves shaft and motor in any direction by necessity and requires 47.0 N·cm or higher holding torque. Controlled by microcontroller, “Arduino” in this case.

Designed head to print with viscous materials requires a tank to keep material intact and push into printer’s head by need. Such material’s flow is achieved mostly by air compressor. Inside of tank, there’s piston which is pushed by fixed pressure (commonly 1-3 bar), that way material pushes until hits rotor’s wall and holds until it rotates. Need to note that pressure cannot be set too high, otherwise material might flow through cavities.

Material’s structure and preparation

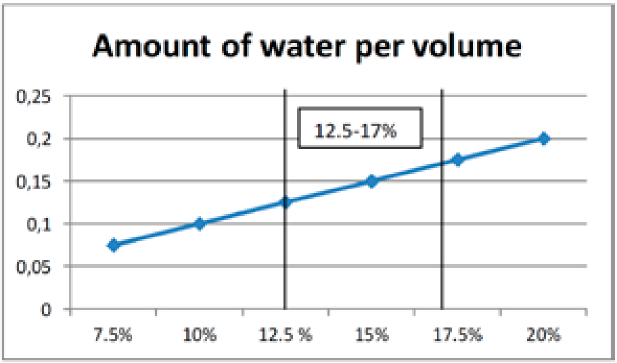
White clay is picked as a main material to conclude its project. Ceramic compounds are used very widely – from pottery to aerospace engineering. Each of ceramic material has its own properties and advantages over metal or polymer (1. Table).

1. Table. Comparison of three main materials

Property	Ceramic	Metal	Polymer
Hardness	Very high	Low	Very low
Thermal expansion	Low	High	Very low
Ductility	Low	High	High
Corrosion resistance	High	Low	Low
Wear resistance	High	Low	Low
Electrical conductivity	Low	High	Low
Thermal conductivity	Depends on material	High	Low
Magnetic	Depends on material	High	Very low
Density	Low	High	Very low

Every kind of clay differentiates by plasticity, adhesive, density, also by structure. There are three main categories based on the fired density of the finished wares: earthenware, stoneware and porcelain. Locally bought white clay goes into earthenware category and is fired on 1000°C temperature. Having no information about clay’s density, it has been estimated with calculations that it’s somewhere from 1.5 to 1.7 g/cm^3.

To achieve softness, material needs to be kneaded while adding little amount of water until it gets to the required plasticity. Attention must be taken into amount of water. Too much water makes clay too sticky and wet, the way printing process breaks down under inability to move a rotor due to the adhesiveness or model collapses due to the wetness. An analysis was conducted about how much water should be added to white clay to meet its required property and results are shown on 4. Figure. It was learnt that an interval from 12.5 to 17% of water per volume is correct amount to make a clay required plasticity. Also there's a possibility to determinate correct plasticity by touching and by the visual observation: softness, easy to wipe, visually glossy.



4. Figure. Required amount of water to achieve plasticity

Every clay compound requires drying processes including firing to achieve final step of modeling. This method dries all water out of clay and makes it hard but brittle.

5. Figure. Clay's flow through nozzle

Conclusion

Despite of achieved material flow control, it is still a long way of development into printing head with capabilities of printing various viscous materials and making one reliable product. Achievement of perfect printing control with such abrasive clay makes head reliable with other abrasive-less materials.

Material range could be expanded with silicone, porcelain, pastes with electrical conductivity. Such materials could be mixed with another 3D printing head and making various innovative prototypes.

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