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DEVELOPMENT OF SOPHISTICATED MECHATRONICS SYSTEM FOR AN INCREASED BUILT VOLUME 3D PRINTER

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Abstract: In today's world, 3D printing has become an integral part of manufacturing system in industries. While there have been numerous innovations considering 3D printing being a moderately old technology, as far as the engineering mindset it's been observed that its potential hasn't been reached and 3D printing Technology can be further made more efficient by many iterations which can give the future a more welcoming manufacturing set of systems and will promise to protect the natural resources and stop wastage of bio products. The project is being focused on the sophisticated mechatronics system for an increased built volume of 3D printer. The result of which is promised by a choosing a better equipped motherboard over the traditional one and improvising the stepper motors to its maximum efficiency. The sensory system has been revamped to make use of all power systems for restricting the over usage of energy so as to conserve and give a better built volume along with being a low-cost 3D printer.

I. INTRODUCTION

Now a days 3D printers are widely used in different fields. 3D Printing can simplify the extended supply chain by which conventional parts are often shipped from many factories around the world. In this project a standard load FDM 3D printer is taken into consideration and its frame is re designed in order to get a higher built volume to increase its efficiency and to provide a better capable 3D printer at a lower cost. For this, the standard pancake stepper motor torque is increased from 42 N-cm to a higher more capable 56 N-cm Nema-17 stepper motor. The Belt drive is selected such that it optimizes the higher torque of the stepper motor to compensate any jerks which might induce unstable extrusions.

II. LITERATURE SURVEY

2.1 Control Boards of 3D printers

A control board of a 3D printer is a part which basically converts all the digital signals into analog. It handles the logical section of a 3D printer which consists of G codes and M codes which is manually fed into the system. It further regulates the temperature requirement of the system which is sensed by a thermistor in the nozzle section and heated bed of the FDM printer. One of the other most important features of a 3D printer is to give motion to the stepper motors for a regulated movement during the print of a prototype.

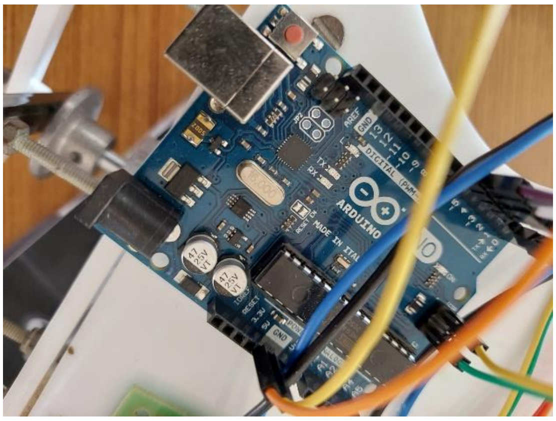

Fig 01: Control Board

A control board of a 3D printer consists of two main components
1. Micro Controller
2. Circuit Board

2.1.1 Elements of a micro controller

1. Processor
2. Memory
3. Input/output Peripherals
4. DAC
5. ADC
6. System Bus
7. Serial Port

Processor – A processor is the brain of the micro controller. It processes the information provided into its system. It is the part of the controller which performs basic arithmetic, logic and input operations.

Memory- The memory of the controller stores the information temporarily provided to the system and sends the information to the processor to process the signals.

Input/output Peripherals- The input/output peripherals basically converts fed input data to the processor by converting it into binary data. It works as a translator between the processor and the outside world.

DAC- It converts the digital signals of the processor and feeds it to the analog components of the system.

ADC- It converts the analog signals of the system such as sensors to digital signals for the processor.

System Bus- It connects all the links of the components of the micro controller together via connecting wires.

Serial Ports- It allows the microcontroller to communicate with external signal [1]

2.1.2 Circuit board

A Circuit board is a basic geometry where all the components of the micro controller is placed. It consists of a wire housing and circuitry organized in a flat board. The system wiring is made of conductive wiring filament.

2.2 Stepper motor

Stepper engines are a significant piece of 3D printers. They are utilized in an assortment of utilizations in the relying upon the kind of uses relying upon the sort of printer. For instance: Stepper engines are utilized to move the extruder or construct stage alone the x, y and z hub. The extruder get together likewise has a stepper engine used to maneuver the fiber into the extruder. Stepper engines are novel in that they can move to a realized span and afterward stand firm on that situation. Since they are a decent engine to move an item to a repeatable position, they are regularly utilized in mechanical technology and in printers.

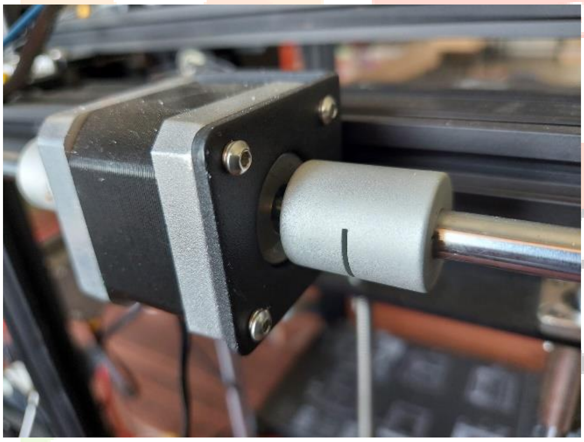

Fig 02: Stepper Motor

2.2.1 Stepper motor types

There are three basic stepper motors. they are:

1.Variable- reluctance
2.Permanent magnet
3.Hybrid

2.3 Sensors

Sensors utilizes for identifying Pressure, moistness, temperatures, gas, speed increase, dislodging, power and shading which are 3D printed and incorporated inside 3D printed structures. New or Hybrid 3D printing process.

Fig 03: Thermistor [2]

2.4 Thermistor
Merriam Webster Online defines a thermistor as "An electrical resistor making use of a semiconductor whose resistance varies sharply in a known manner with the temperature".
Thermistor is a significant part in FDM printers.
Before we talk about its work, we should characterize what a thermistor is:
Thermistor is short for "Warm Resistors", are electrical gadgets whose opposition changes with temperature.
There are two kinds of thermistor:
Negative Temperature Coefficient (NTC) Thermistors: Thermistors whose opposition diminishes with expanding temperature. Most regularly utilized sort in 3D Printing is NTC
Positive Temperature Coefficient (PTC) Thermistor: Thermistors whose opposition increments with an increment in temperature.

2.5 Drive Trains Of 3D Printers
2.5.1 Drive train definition
Drive train is characterized as a system where a gathering of parts of an engine vehicle that conveys capacity to the driving wheels. This bars the motor or engine that produces the power.

2.5.2 Working of Drive Train
1. This is the order in which power is generated and provided by a drive train.
2. The motor will deliver energy to control a flywheel.
3. That flywheel works with the transmission to control the measure of force scattered to different pieces of the drive train
4. The drive shaft twists to deliver capacity to a differential.
5. Later that the differential supplies power from every one of those drive shafts parts and blast your wheels are moving

2.5.3 Belt Drive
It is as a circle. It associates precisely two shafts for sending power easily starting with one shaft then onto the next.

Fig 04: Belt Drive

2.5.3.1 Belt Drive and its Types:
Belt drive comprises of two shafts and a belt. One of these shafts is an engine shaft on which electric engine is mounted. On the other shaft, the machine is mounted to which power is communicated by the belt drive. Regularly speed of the engine is high since rapid engines are more productive. Accordingly, engine shaft is the driving shaft and the machine shaft is the determined shaft. There are two sorts of belt drive, in particular level belt drive and V-belt drive. In this drive, both drive and driven shafts continue to run a comparable way. For smooth power transmission, belt on one side is tighter than the contrary side. In an even drive, the decent side is continually kept in the lower side of two pulleys because the hang of the upper side possibly extends the edge of contact of the belt on the two pulleys. More edge of contact suggests more power transmission.
A belt is a circle of versatile material used to precisely associate no less than two turning shafts. routinely equal. Belts may be used as a wellspring of development, to communicate control viably. of course, to follow relative turn of events. Belts are hovered over pulleys, furthermore, may have a bend between the pulleys. Moreover, the shafts require not be equal. In a two-pulley structure. the belt can either drive the pulleys consistently one way (the equivalent if one qual shafts). then again, the belt may be crossed. with

the objective that the heading still up in the air shaft is (the alternate way to the driver if on equal shafts). As a wellspring of development, a vehicle line is one application where the belt is acclimated to incessantly pass on a store between two core interests

2.6 Mother Boards of 3D Printer

The motherboard is the heart of every 3D printer. The mother board controls the main component of 3D printer which is the microcontroller. The microcontroller's function is to be the path between the machine codes and final product of the 3D printer. The micro controller is not only limited to giving directions to the stepper motors for right directional movement but also to receive and respond to various sensor-based elements housed in the 3D printer such as extruder temperatures and state of the limit switches. Basically, a motherboard acts as a intermediate between the hardware and software existing in the 3D printer.

2.7 Low-Cost 3D printer

In this Report, Raúl Vallejos Baier et al. researched on the following objective that Additive manufacturing encompasses a collection of techniques to manufacture structures from a computational model. Among them, fused deposition modeling (FDM) relies on heating thermoplastics to their fusion point and extruding the material through a nozzle in a controlled pattern. In this paper, porous samples were manufactured in the printer and were compared with samples manufactured in an equivalent commercial desktop FDM printer, in terms of microstructure and compressive mechanical performance.[3]

2.8 Ender 3 3D printer kit transformed into open, programmable syringe pump set

In this Project, Sander Baas et al. performs an operation on a cheap, open-source 3D printer is transformed into an Open Hardware, programmable syringe pump set. Simply 3 sections should be bought outside of the printer unit. Any remaining parts are either in the Ender 3 unit, or can be 3D printed. They can glance through the inward functions of the 3D printer component in this venture. The siphons are constrained by the 3D printer firmware and motherboard and customized in straightforward G-code text records. Siphons utilizing plans for making an interpretation of rotational movement to direct movement utilizing a lead screw, are impacted by the nature of the engines/drivers and by the underlying steadiness of the mechanical assembly. The engines and drivers utilized here have been utilized in 3D printing since numerous years, and normally a bombed 3D print can be followed back to a disappointment in the hot-end or the extruder, and just seldom to the XYZ movement of the printer.[4]

2.9 Design and implementation of a low-cost bio-printer modification, allowing for switching between plastic and gel extrusion

In this Project, Adolf Krige et al. completed a project on a low-cost switchable bio printer. They stated that due to due to the high cost of bio printers it is not feasible for proof-of-concept experiments or educational purposes. Furthermore, the more affordable DIY methods all disable the plastic printing capability of the original printer.[5]

III. PROBLEM STATEMENT

From the above papers it is understood that the current available fused deposition modelling 3D printers are lacking the potential of an increased output volume which can further increase the production rate of the printer. Therefore, it is found that a sophisticated mechatronic system for an Increased build volume 3D Printer is required.

IV. DESIGN PARAMETRS AND CALCULATIONS

4.1 Selection of Motor for X and Y axis Assumptions:

Constant speed of the motor = 600rpm=10 rps

$v = r * \omega$

$\omega = [2\pi N]/60 = 62.83$ rad/min

Therefore,

450 = r*47.12

r = 9.550 mm

Torque = Force*Radius Force = 0.586 N

(Considering NEMA 17 stepper motor having torque = 56N-cm)

4.2 Selection of Belt Drive

For the given problem statement, it is found that in order to find the balance between the stepper motor's increased torque and power, a suitable Belt Drive mechanism with a robust and balanced coefficient of friction is an ideal choice. Therefore, for this project a belt drive mechanism is selected.

4.2.1Calculation for Timing of Belts

4.2.1.1Design of timing belt for X and Y axis:

D=d= Diameter of pulley = 2cm

C = Center distance between two pulleys = 700mm

L = Length of the timing belt

$L = \frac{\pi}{2}(D + d) + \sqrt{4c\,2 + D2 + d\,2}$

L=1.46319m

The ultimate strength of polyurethane = 20.77MPa

Considering FOS = 4

Force = 40N (From Motor)

$\sigma = \frac{F}{A}$

Area = 7.703 mm2

Width=5.925mm

Standard width=6mm

Conclusion for timing belt selection

The width of the belt is found to be 5.925mm and standardized to 6mm. MXL pitch of 2.032mm is selected for smooth movement.

4.2.1.2 Design of timing belt for Z axis

D=d= Diameter of pulleys = 15mm
C = Center distance between two pulleys = 0.736m
L = Length of the timing
T=Thickness of the belt = 1.3mm

$L = \frac{\pi}{2}(D + d) + \sqrt{4c\ 2\ +\ D2\ +\ d\ 2\ L} = 1.540$ m

The ultimate strength of polyurethane = 20.77MPa
Considering FOS = 2
Force = 250/2=125 N (From Torque of NEMA 23 – 150Ncm)

$\sigma = \frac{F}{A}$

Area = 12.03mm2
Width=9.25mm
Standard width=10mm

V. Conclusion

The conclusion of the current problem statement is achieved by selecting a salient mother board over an ordinary one and modifying the stepper motors to its maximum efficiency and force. The torque of the stepper motors is calculated and implemented for providing a faster rate of deposition to compensate for an increased output in the print bed. The sensory system has been revamped to make use of all power delivery for restricting the over usage of energy so as to conserve and give better input to output ratio which is the objective that is to manufacture a low-cost 3D Printer.

5.1 Calculation of stepper motor parameters

Table: 5.1 Selection of Motor for X and Y axis Assumptions:

SL NO	Velocity	Angular velocity	Radius	Torque	Force
01	600rpm	62.83 rad/min	9.550 mm	56 N-cm	0.586 N

Table: 5.2 Design of timing belt for x and y axis:

SL NO	Diameter	Centre distance	Length of belt	Ultimate Strength	Force	Stress(σ)
01	200mm	700 mm	1.4m	20.77M pa	40 N	5.194N/mm^2

Table: 5.3 Design of timing belt for Z axis:

SL NO	Diameter	Centre distance	Length of belt	Ultimate Strength	Force	Stress(σ)
01	15mm	736 mm	1.540m	20.77M pa	125 N	10.39N/mm^2

6.2 Selection of Mother board

For this project, Smoothie board v1 is taken into consideration. This is taken because of the feature of its integrated micro-controller and capability to take upto 5-Built in Stepper driver. It also runs under an Open-Source firmware known as Smoothie ware which gives access to numerous support systems. This motherboard gives USB interface and ethernet for a faster data transfer. The Microcontroller houses a 32-bit- architecture and a 120 MHz frequency. It supports SD card storage of upto 2GB. It contains a temperature reading 4 temperature reading inputs and 6 endstops input. The power unit supports 12V to 24V.

VII. Acknowledgement

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We are overwhelmed in all humbleness and gratefulness to acknowledge my depth to all those who have helped me to put these ideas, well above the level of simplicity and into something concrete.

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