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Low Cost with Vibration Controlled Efficient Fused Deposition Modeling

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Abstract**: *Fused Deposition Modelling (FDM) is an innovative system that can create necessary items and are significant to generate distinctive styles of articles, in unusual supplies, completely from the uniform system. FDM machine can build fair model everything from stoneware to synthetic dolls, iron machine parts, decorative chocolate cakes or regular human body parts. FDM can supersede conventional factory industrial unit with only machinery, simply like printing press swapped by bottles of ink. Nowadays these machines are available at higher costs and are used only in industrial areas. With technology available and the material used in these machines proposes a system that sparks upon making a low cost-efficient machine and materials by designing a rigid frame for the 3D printer. The result shows low cost 3D printer prototype of FDM machine and the vibration analysis with various speed at various stages for the product outcome.***

Keywords **: *FDM, Vibration, Speed, 3D printing, Filament.***

I. INTRODUCTION

Fused Deposition Modelling (FDM) is an additive processing machine that makes three-dimensional (3D) objects. Fused Filament Fabrication (FFF) machines [1] can do multicolor prints with multiple nozzles. Depending upon inside filling patterns [2]of the system that makes object strong and also useful for rapid prototype [3]. In [4], the author has suggested a wide range of filaments with proven tests. In order to maintain the temperature of the heated bed and the Filament heater [5], software control and fans has been used to control the temperature accordingly.

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The process of 3D printing was done by layering down predetermined slice height onto the heated bed that becomes an eventual object. Conventional printers use ink cartridges, instead FDM use filaments that are fed into a heater to obtain the final product [6] and has discussed about the SLA machine as well as 3D-printer. 3D-printer arrays are good, but the SLA machine was resin based that was costly and very messy, so FDM machines are better to use. By changing the tool head, it can be also used in food industries [7] for icing complex cakes, chocolates, etc. According to the parameter that was given to 3D object which determines the quality and runtime of that particular object.

The downside of FDM machines was that it can cause high vibrations [8] and layering artifacts if the system was not stiff. This machine can be a cloud-based machine [9] by connecting over a network to work wirelessly. As [10] has suggested if flexible filaments are used, it will be useful for making wearable applications. In [11], has mentioned by changing the tool head of the machine finds its application in biomedical fields for making braces, a prosthesis for humans. The system based on an open firmware called Marlin [12] that was easy to configure, so any common person can change the parameters. Basically, the firmware is used to control every component from motors to filament heater and heated bed. Here the firmware has been tweaked according to the proposed system. Limit Switches are sensors that are used to maintain the heated bed and filament heater to stay within the boundaries of the machine, [13] has hall effect sensor as limit switches for their system. Based on the results of [14] temperature analysis, the system uses parameters to PID auto-tune the Filament heater and heated bed, that was useful to maintain the power supply. As discussed in [15], the impact of vibration that determines the overall print quality as well. 3D to 2D conversion path parameters [16] has been used for tool path planning that was obtained by inverse mapping.

The proposed work discusses about the low cost FDM 3D printing mechanism by reduced vibrations with various speeds to improve the quality of printing. The rest of the paper discusses about the problem statement by overcoming the difficulties faced by the existing FDM printing model in Section II. The System Architecture are presented in Section III. Section IV gives the simulation and experimental results, followed by discussion. Section V concludes and highlights the future work.

II. PROBLEM FORMULATION

The existing FDM system has the effect of vibrations that affected the quality of the prints or object. The proposed work has made an attempt to overcome the problems faced by the existing system. To overcome the effect of vibrations at higher speeds, the proposed work uses tennis balls as dampeners to absorb the vibrations so that the quality does not get affected. The proposed work also uses diagonal supports for the frame, spring coupler for z-axis, the LCD controller for ease of access, 3D printed fan ducts for cooling down the filament, the secured fuse power socket and added plywood to support the entire system. The following section depicts the system architecture that describes more about the functioning of FDM with reduced vibrations to improve of quality of the object.

III. SYSTEM ARCHITECTURE

The proposed system uses Poly Lactic Acid (PLA) was environmental friendly, biodegradable filament and more cost-efficient. The proposed system uses an actual thermistor to maintain the target temperature. In order to overcome vibrations caused by the machine, the proposed system uses ball dampeners that act like shock absorbers and drastically improves the overall print quality. This system can do color prints in a single nozzle with a respective count of the extruder and it's more of cost effective. Normally, open relays act as limit switch, so when the filament heater or the heated bed tends to move out of the boundary it hits the limit switch that sends a signal to the motherboard to stop the respective motor. For added rigidity, the system uses wooden plywood to support the frame structure from below which improves the overall quality of prints.

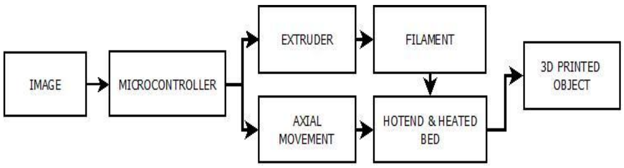

Fig.1. Functional block diagram of FDM system

Fig.1. shows the functional block diagram of FDM system with printing mechanism. First and foremost an image is taken, and it is converted into a 3D model using a software called Tinkercad. After creating, the model is imported to another software called Ideamaker that is used to slice the 3D model layer by layer and gives an output in the form of G-codes. G-codes is a type of machine language used for axial movements in CNC machines. The G-codes are uploaded to the microcontroller; the microcontroller controls the axial movements (XYZ axis) in coordination with the extruder. The extruder is another stepper motor which is used to push the filament down to the hot-end (filament heater). The hot-end melts the filament and layers it down on the heated bed. Thus, after several layers of printing raises the Z axis and the final 3D printed object was obtained.

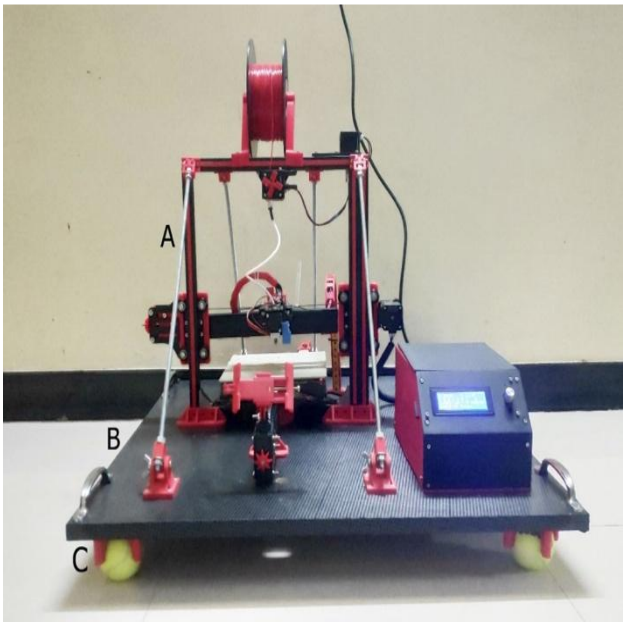

Fig. 2. Prototype of FDM printer

Fig.2. shows the working model of FDM printing mechanism. As shown, the identified part A is the machine itself, B is the plywood which holds the machine and C is the tennis ball dampeners which supports the entire FDM printing to reduce the vibrations. The red color highlighted in machine are the parts manufactured by our proposed FDM printer that uses the red color filament. Upon printing, the results observed at various speed to check the system rigidity analysis are analyzed in results and discussion section.

IV. RESULTS AND DISCUSSION

The results obtained at various speeds with different stages of system rigidity are shown in Fig. 3. at a speed of 30mm/s, Fig. 4. at a speed of 40mm/s and Fig. 5. at a speed of 80mm/s.

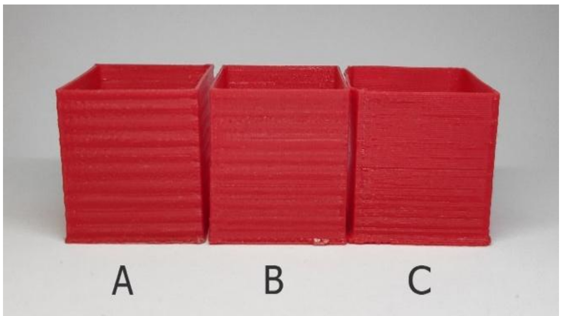

Fig. 3. Speed at 30mm/s

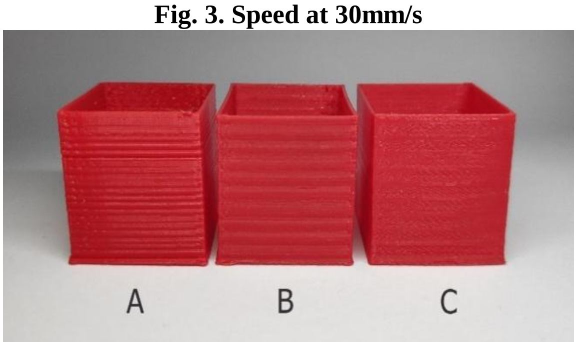

Fig. 4. Speed at 40mm/s

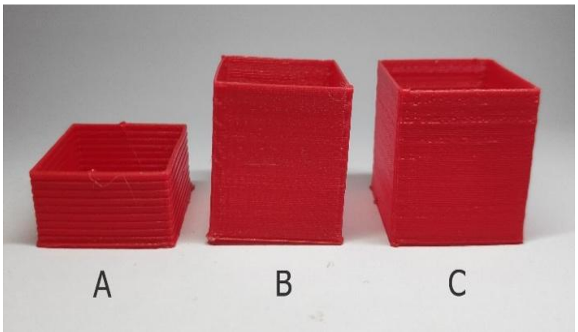

Fig. 5. Speed at 80mm/s

From Fig. 3, 4 and 5. 'A' shows the cube is printed without any support (machine is placed in bare floor) that has rough surface. 'B' shows the cube is printed with plywood and diagonal support (machine placed over the plywood) where the quality of printing is improved. 'C' shows the cube is printed with tennis ball dampener support which is placed below the plywood and has fine quality when compared to others. The results obtained further analyses the vibration and speed at axis levels to test the limit of the machine.

A. Vibration Analysis

Vibration analysis calculates the artifacts produced in printed objects with a predetermined time interval. Three different flow rates are obtained individually for each axis and calculates the average of peak values. This analysis is done twice, once before adding ball dampeners and another taken after installing ball dampers, thus giving an overall average percentage between these two individual tests. For this analysis, software called (iNVH) powered by Bosch was used in-turn calculates the acceleration produced in all three axes and gives an output waveform in (.CSV) format.

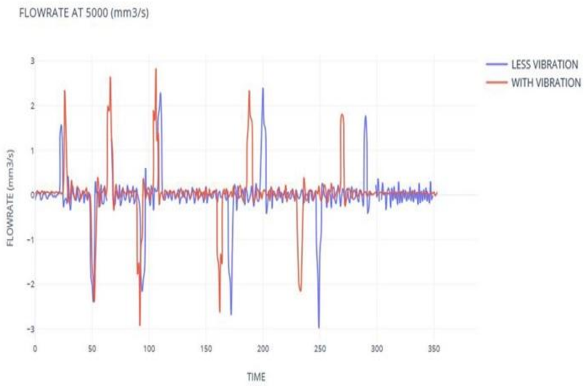

Fig. 6. X-axis at 5000mm^3/s

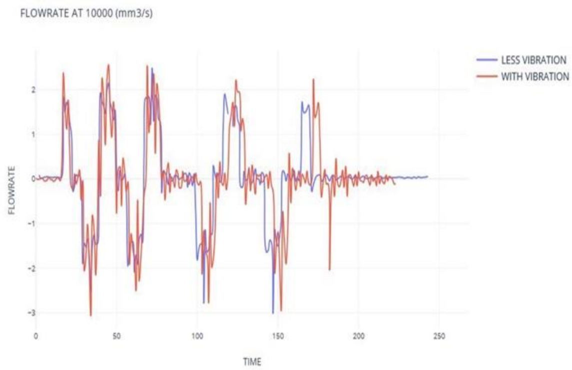

Fig. 7. X-axis at 10000mm^3/s

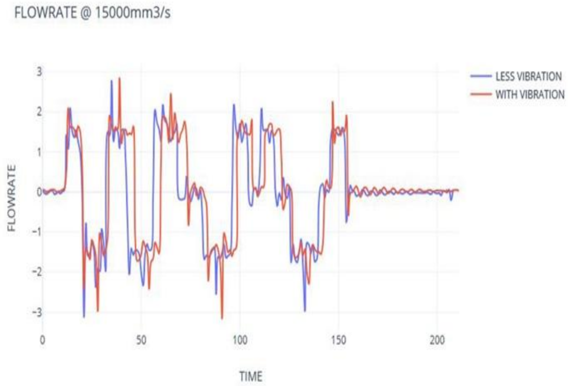

Fig. 8. X-axis at 15000mm^3/s

From Fig. 6 – 8. it was observed that the x-axis overall average percentage efficiency at peak points for various speed of 5000 mm^3/s,10000 mm^3/s and 15000mm^3/s are 26.14% 24.04%and 19.99% respectively.

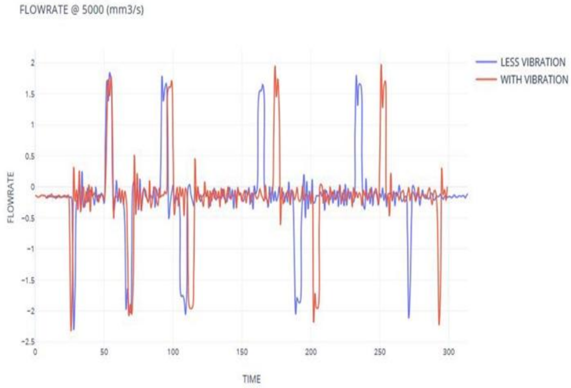

Fig. 9. Y-axis at 5000mm^3/s

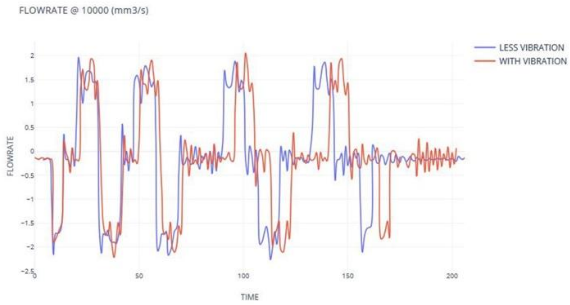

Fig. 10. Y-axis at 10000mm^3/s

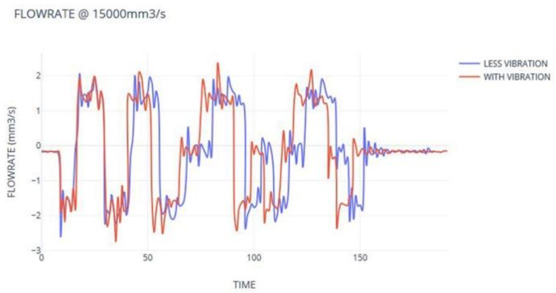

Fig. 11. Y-axis at 15000mm3/s

Similarly from Fig. 9-11. the y-axis overall average percentage efficiency at peak points for various speed of 5000 mm^3/s,10000 mm^3/s and 15000mm^3/s are 17.84%,17.34% and 17.21% respectively.

From the above analysis, it was clear that overall average efficiency was greater when the flow rate was less, thus giving good quality prints. In turn if the flow rate was more, the overall average percentage was reduced thus giving a degraded quality of prints. The reason was that the x-axis contains the Filament heater, which weighs around 0.280 kilograms, but y-axis however, contains the heated bed itself, which weighs 1.2 kilograms thus making the y-axis to vibrate more due to inertia caused by the sudden motor movements.

V. CONCLUSION AND FUTURE WORK

FDM machine was fully functional, capable of modeling an object of 200mmx200mmx200mm in volume. Therefore, the proposed working model can be used to prototype according to user preference that was rugged and more precise. In terms of current regulation, the observation made was that these machines consume less power, works on the best quality according to user preference. For future works, it is intended to develop educational models as well as commercial models under reasonable prices intended for a small desktop fabrication. In order to develop a commercial type machine, the proposed model has to have more precision, develop models for different types of prototypes. This working model can be automated without any human intervention, can be connected through the internet and be used remotely. Some of the issues are related to the fact that robotic machines have a higher scope than normal manpower. The proposed model can maintain privacy, informed consent, Cybersecurity and data ownership also plays an important role in these machines.

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