Large Scale 3D Printer Mechanism Simulations

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Abstract

3D printing is projected as the next industrial revolution. Most of the available 3D printers are small scale 3D printers. Current Industrial need is for Large scale 3D Printers to manufacture realistic 3D Printed products effectively with less cost compared to commercial production process and operations. Also for heavy weighted printing process build platform has to be maintain at fixed position to reduce the deflection effect on whole assembly of a 3D Printer.
Among Cartesian type, many types of Mechanisms are majorly using now a days. In this simulation process the mechanism movements in a complex 3D printer design are modeled to determine the displacements and to observe the working mechanism. The Parametric model has been built by Comsol CAD model designer and analysed by Multibody Dynamics Simulation Software. The displacement results and animation are Extracted to visualize the mechanism of the 3D printer.

Keywords: 3D Printer, COMSOL Multiphysics, Multibody Dynamics Analysis, Multiphysics CAE.

1. Introduction

Current need is for Large scale 3D Printers to manufacture realistic 3D Printed products effectively, compared to commercial production process. For larger scale printers, the part size and resolution are conflicting requirements. Reliable large scale 3D Printing requires in depth understanding of the functional Mechanisms. Cartesian 3D printers are dominant compared to other printers like Delta and Robotic arm because of their simple construction. Current 3D printer are having limitations in print rate and part size. The challenge for large part 3D printing are print resolution and print speed, which is governed by the printer mechanism. In this paper, brief review of available 3D printer mechanism are given. The printer mechanisms are simulated in COMSOL using Multibody dynamics module. Flexible and rigid mechanism simulation are performed for evaluation of the print mechanism and structural performance. This study, in future will also include 3D printing manufacturing method simulations.

2. 3D Printer Mechanisms and Simulations

Major Types of 3D Printers are classified as Cartesian, Robotic arm and Delta 3D printers. CAD model of 3D printing Mechanisms are shown in figure 1. Cartesian printers have three different positional mechanics. Robotic arm 3D Printer with 6 dof are used due to their flexibility and powerful programming capability. Delta 3D Printer have three identical axis of movement. This reduces the number of unique parts and makes for simpler construction. Cartesian 3D printers are wided used in the industry due to its simplicity in construction and ease of operation. CAD models of Cartesian Printers are shown in figure 1.

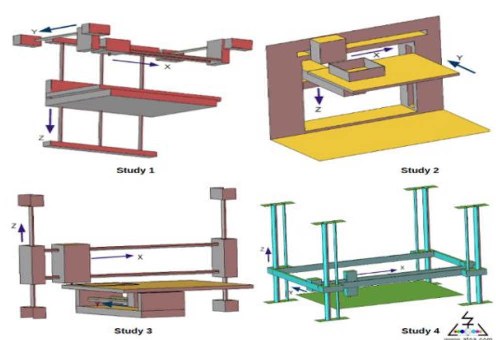

Figure 1. CAD models of different types of Cartesian 3D Printer Mechanisms

Parametric model of 3D printer was developed. The mechanisms and structural performance was investigated using Multibody Dynamics and Structural mechanics module. The displacement results and animation of a building a square box are extracted to visualize the mechanism of the 3D

printer. Simulation are made with flexible attachments and prismatic joints to guide the X Y Z movements.
Displacement and Von Mises stresses are calculated for Delta 3D printer and for rack and pinion printer. In addition to this, torque load calculations and effect of acceleration on displacement were studied on rack and pinion printer.

3. Results and discussions

The effect of gravity loading, G forces along with multi body simulations are investigated for all product design made. Parametric sweep node is used to extract the displacement results at different positions and Animations plots for the mechanisms. Displacements and animations results for Delta 3D printer is shown in figure 2-4.

3.1. Delta 3D printer

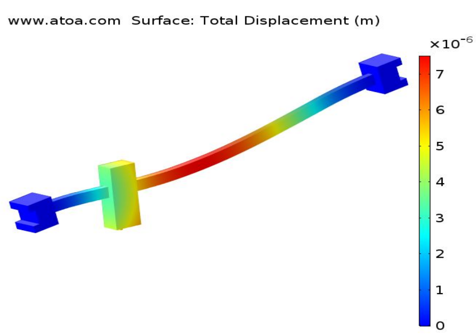

Figure 2. Displacement plot of Extruder axis.

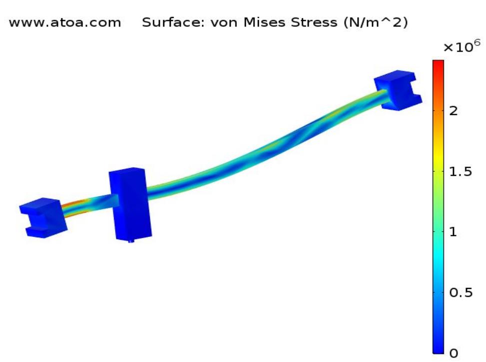

Figure 3. von Mises Stress plot of Extruder axis.

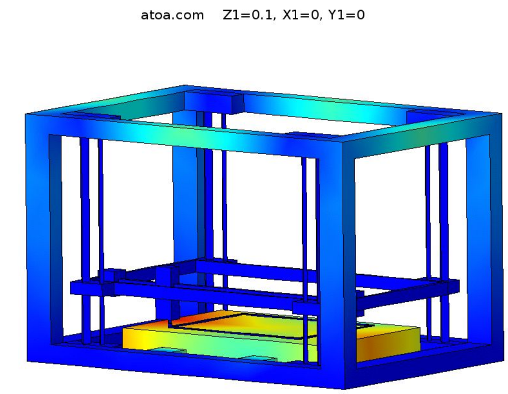

Figure 4. Animation plot for Cartesian printer

3.2. Rack and pinion Printer

For rack and pinion printer, displacement results for frame, track support and full rack and pinion printer are shown in figure 5-7.

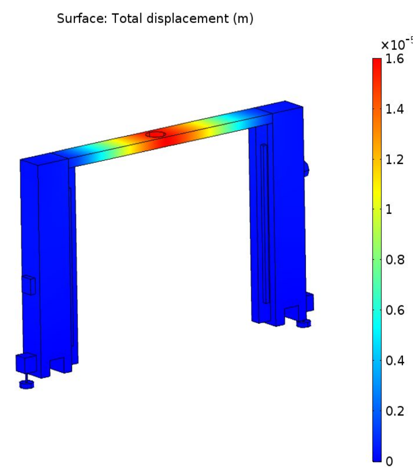

Figure 5: Displacement plot for a Frame

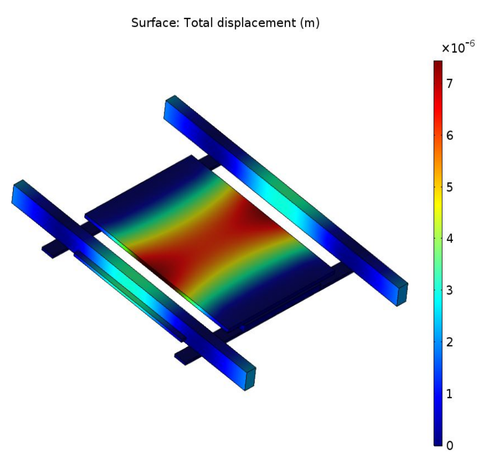

Figure 6 : Displacement plot for Track support

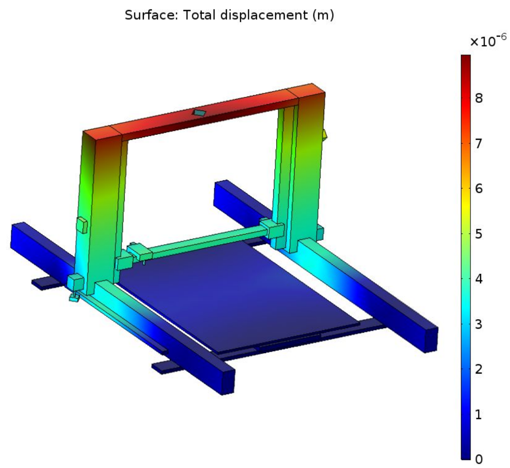

Figure 7: Displacement plot for rack and pinion printer

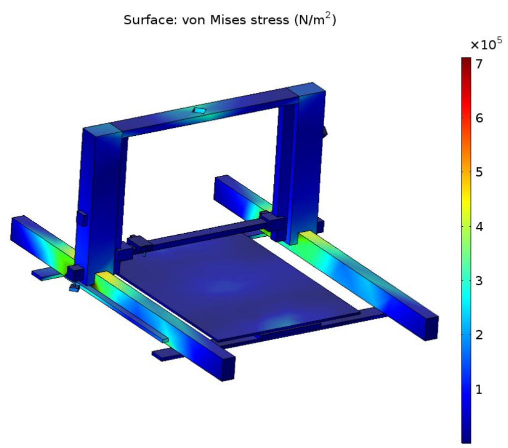

Figure 8 : von mises stresses for rack and pinion printer

3.2.1. Effect of torque on displacement

If the motor on one end of the frame is failed, then it creates torque on the other end.The torque generated on the other end is simulated. Displacement and von mises stresses are shown in figure 9-10.

Torque Load Calculations

Acceleration a	5	m/s^2
Radius of the Motor Shaft = r	2.5	mm
Mass of the Extruder Assembly and Z motors	5	kg
Mass of the Y components and X Motors	15	kg
Mass of the Frame assembly	20	kg
Total Mass of System without Track and Build Platform	40	kg
Total Mass of LS3DP 3D Printer Estimation	50 max	kg
Force Required to accelerate the mass of the components F=ma	200	N
Torque required to move the whole frame assembly T= F*r	0.5	N-m

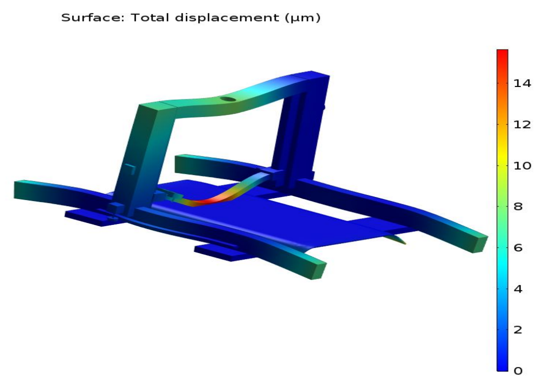

Figure 9: Displacement due to torque

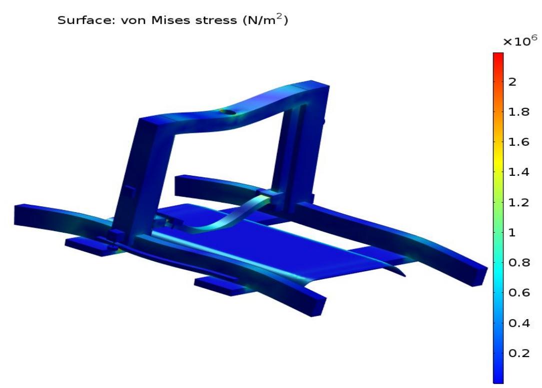

Figure 10: von mises stresses due to torque

As per the torque load calculations from above, it is calculated that a torque of 0.5 N-m is generated at the other end of assembly. Maximum displacement and maximum von mises stresses results values are found to be within acceptable limits.

2.2 Effect of acceleration on structural displacement

Here 3D printer head with travel speed of 1 to 5 g_const has been considered to analyse the structure along with all the required payload condition on A Frame.
Following plots are presented to show that the acceptable level of travel speed and their deflection effect on 3D printer head with 1g and 5g Speed condition.

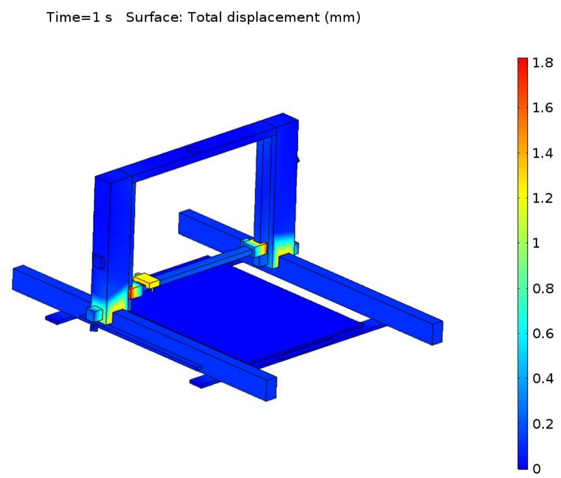

Figure 11: Displacement at 5g acceleration

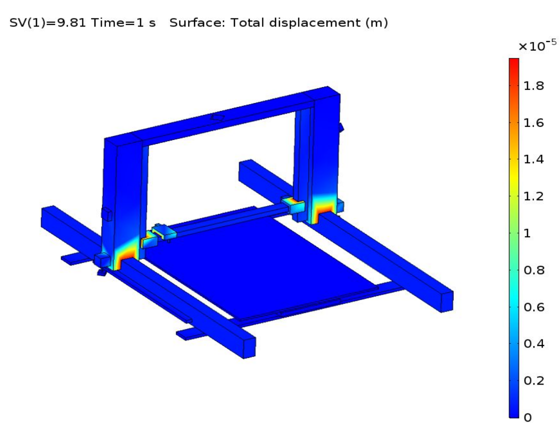

Figure 12: Displacement at 1g acceleration

Displacement values at 1g and 5g acceleration speed are 0.18 microns and 1.8 mm. The displacement value at 5g acceleration is much higher than compared to the 1g acceleration but still within lower and acceptable range.

4. Conclusions

The simulation results shows that the visualization of 3D printing Mechanisms helps in the selection and customisation of 3D printer for a given product or part fabrication. Multibody dynamics simulation on a flexible body shows the deflection and stress levels due to normal working payload, gravity and g- forces effects of the 3D printer for optimization. The trade off between printer size and part print resolution can be optimized with these simulations. These parametric physics based scaling models can be used from micro to macro level printer for overall performance evaluation.

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