University of Southern California

Department of Aerospace and Mechanical Engineering

AME 554

Additive Manufacturing Technologies

PROJECT REPORT:

COVID-19 Killer

A Smart Alcohol Sanitizing Robot

Group Members:

Chih-Yi Wu chihyiwu@usc.edu

Jiaoran Wang jiaoranw@usc.edu

Yaan Wang yaanwang@usc.edu

Abstract

Firstly,

Secondly,

Then the structural experiments, dynamics simulation (Finite Element Analysis) and parameter correlation analysis are applied to the design and 3D printing parts

Chapter 1 Introduction

1.1 Additive manufacturing

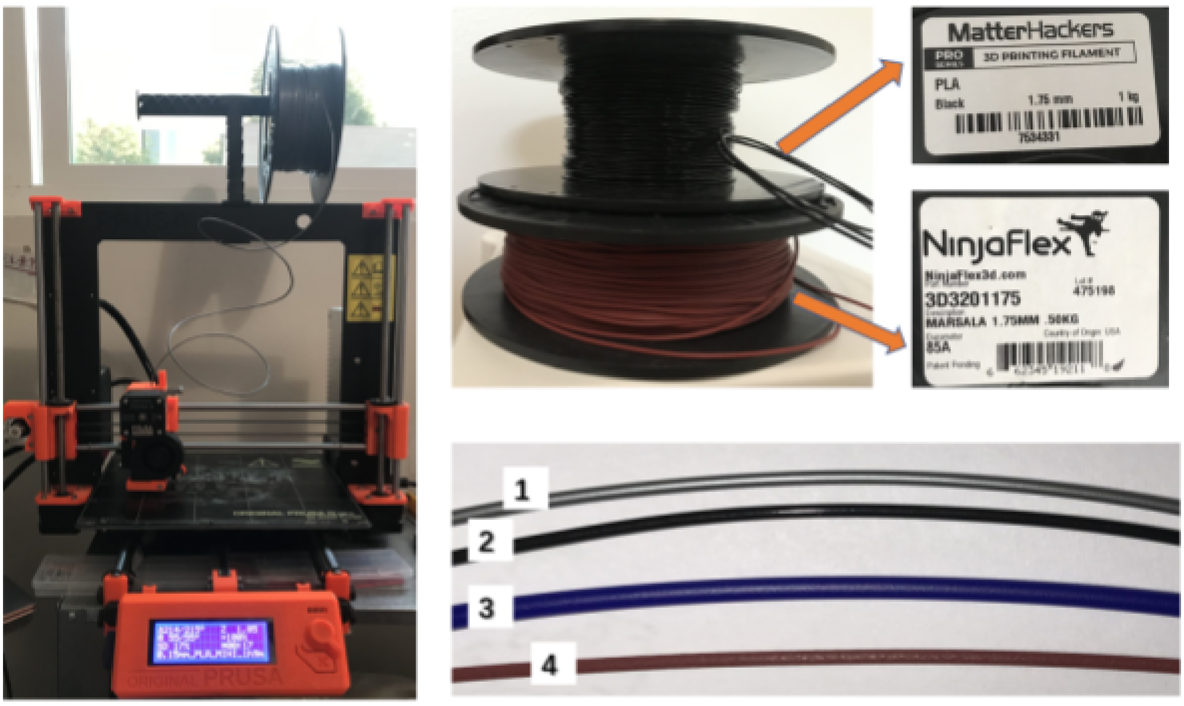


Figure 1-1. PRUSA i3 MK2 and Filaments

Additive Manufacturing is a process in which a component is built layer by layer. In this report, the AM technique combined with Fused Deposition Modeling (FDM) method is used for 3D Printing components. The PLA is used as printing filament material.

1.2 Design Background

1.3 Project Description

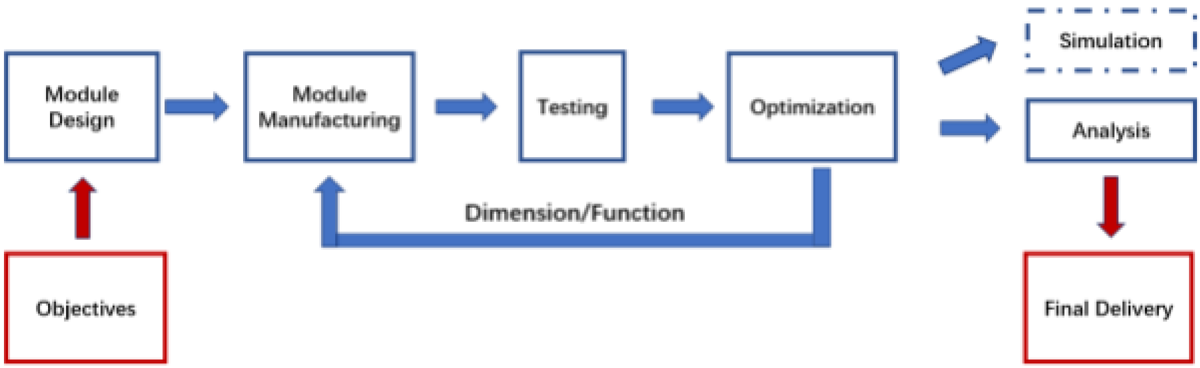


Figure 1-1. Production Process Diagram

Chapter 2 System Components and Modeling

2.1 Introduction

The COVID-19 Killer was built with three parts: a disinfectant spraying device, a robot car and 3D printing components.

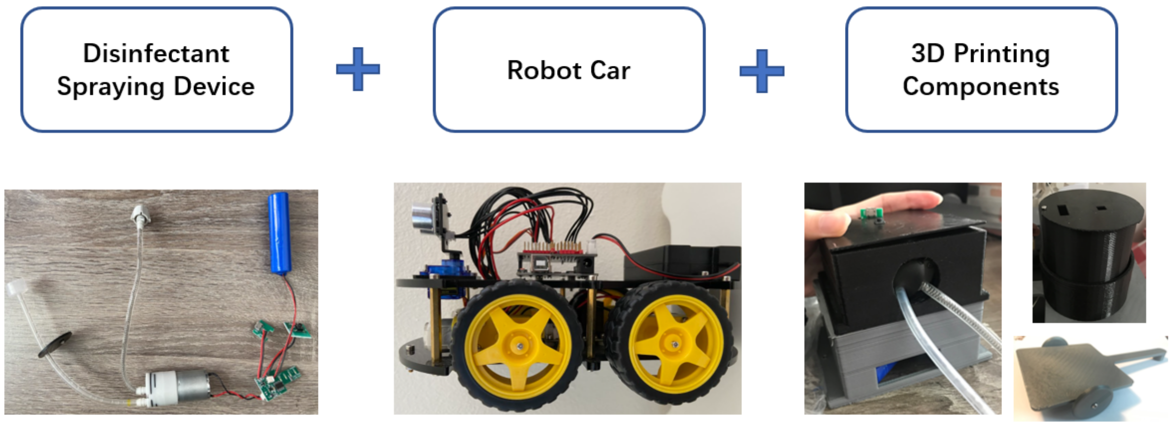


Figure 1-1. Assembly of the COVID-19 Killer

2.2 Disinfectant Spraying Device

A disinfectant spraying device was integrated within the robot car. The device contains a battery, a PCB, a water pump, a spray nozzle and a suction nozzle to pump and spray alcohol. The PCB was connected with a switch to turn on the motor, and the switch was put on the top of the cover for users to press the button. Moreover, a USB port was also put on the top of the cover for charging.

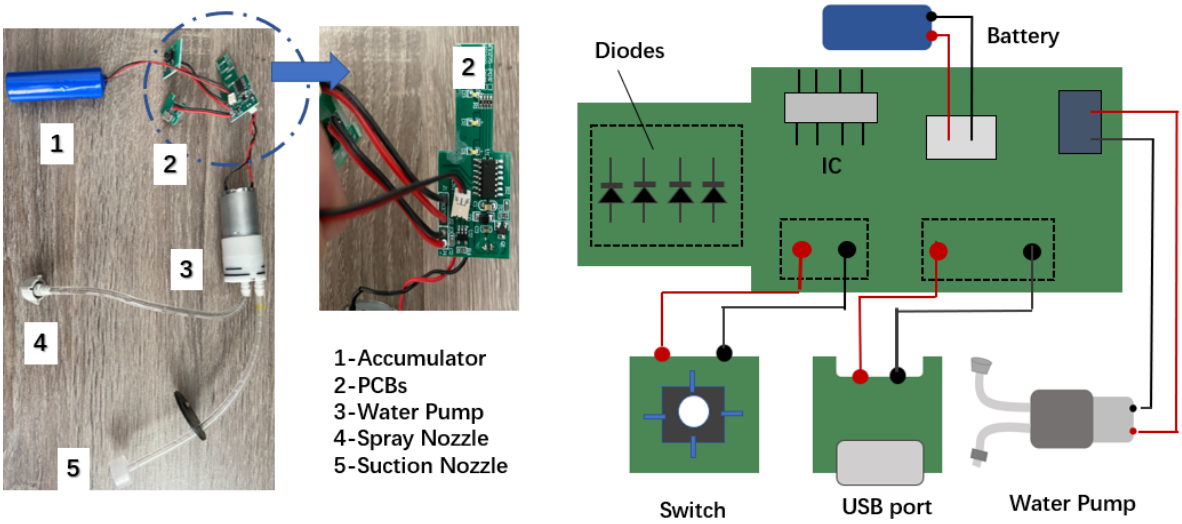
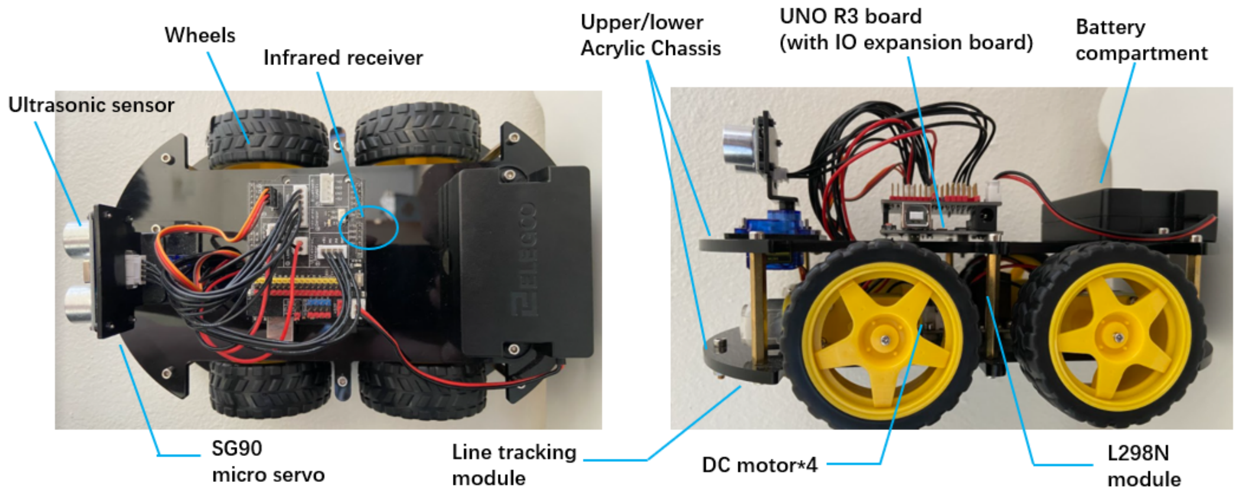


Figure 1-1. Spray System Components (left); PCB Schematic (right)

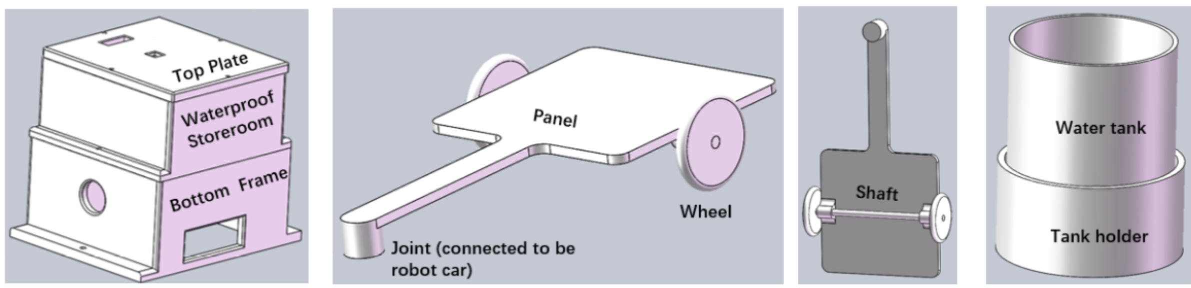
2.3 Robot Car

The Elegoo Smart Robot Car was used to be the main body of our robot. The control panel is the UNO R3 board, a kind of Arduino. Moreover, the car has a line tracking module on the bottom for line tracking, and an ultrasonic sensor to detect obstacles or the difference in reflective services. The car can go with 5 modes, and the obstacle avoidance function was chosen to be our control method.

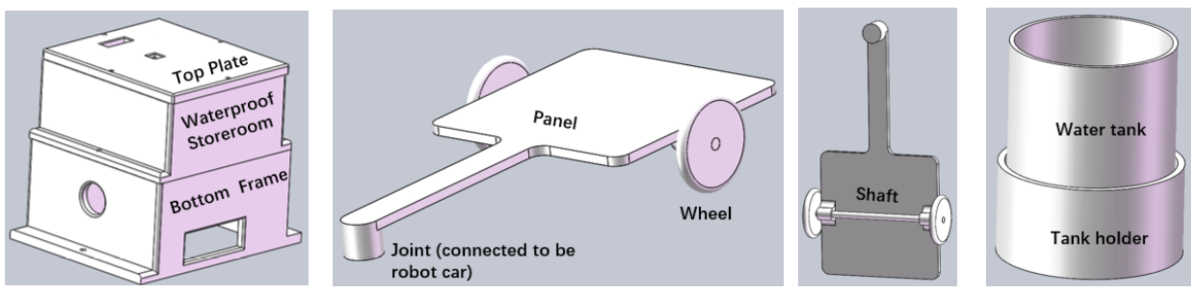


2.4 Components

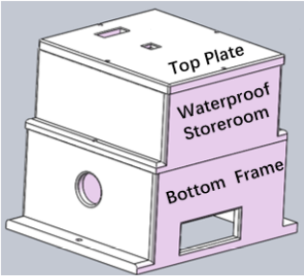
2.4.1 Isolation Shelf

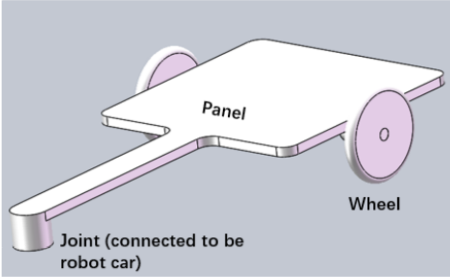


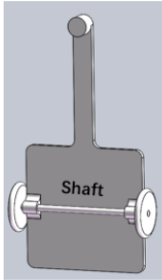
2.4.2 Trailer

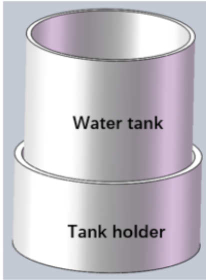


2.4.3 Water Tank

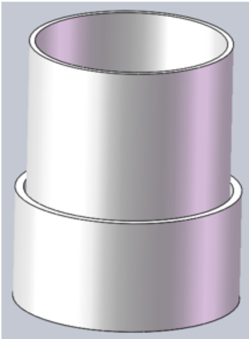






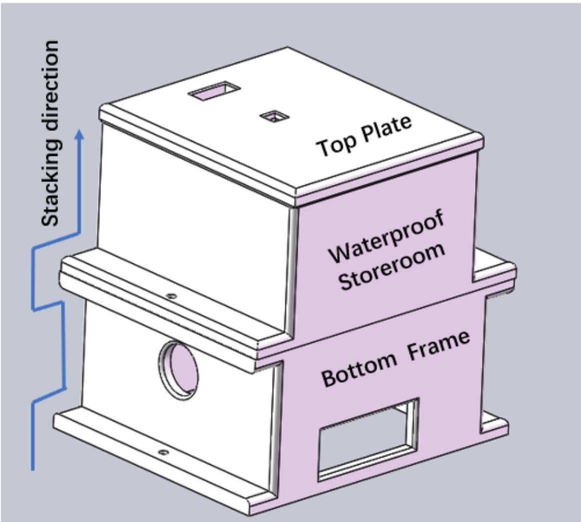


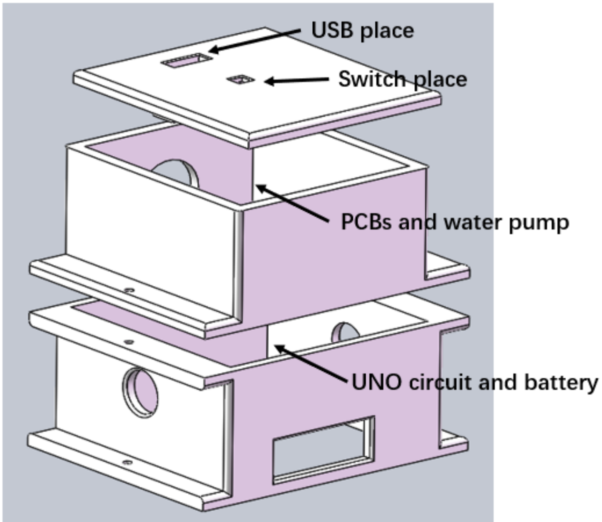
***** trailer: Maximum rotational angle
******* Tank Volume



91% Isopropyl alcohol density: 0.786 g/cm^3

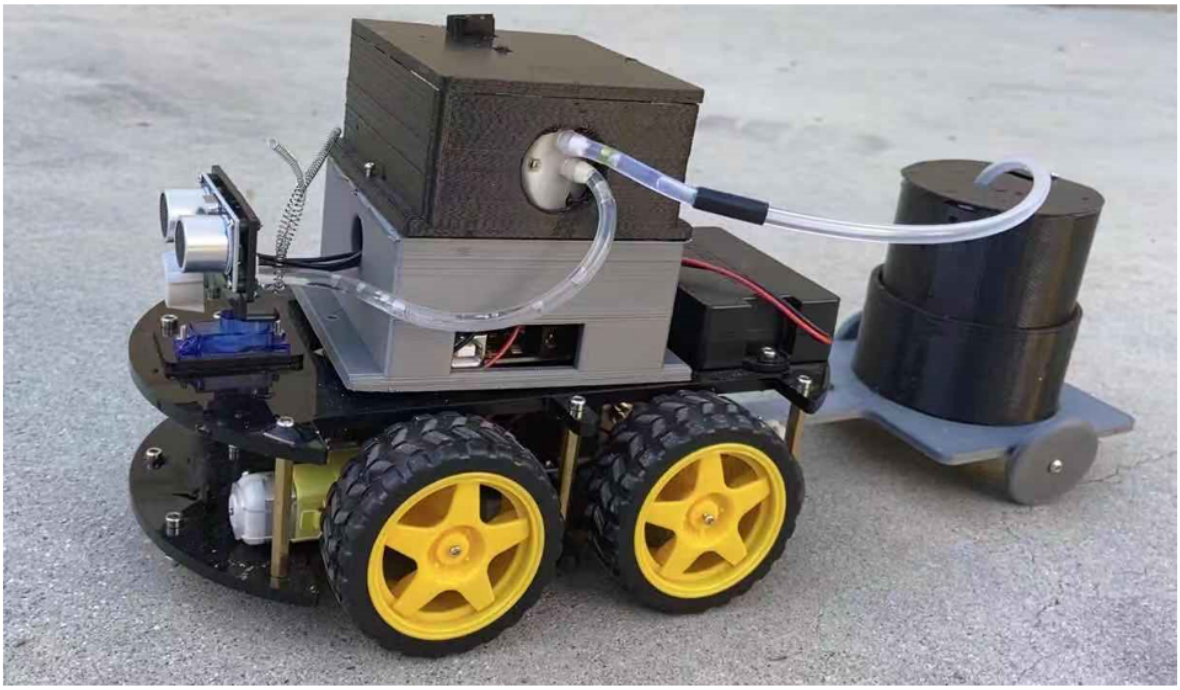
Volume = 307875.82 mm^3
=307.88cm^3
Weight = Weight_tank +Weight_alcohol
Maximum alcohol weight = 242g





2.5 Assembly

The tank holder was fixed on the trailer, and the water tank can be separated from the holder. Thus, when the car runs out of alcohol, the tank can be taken to fill up and put back to continue spraying alcohol.



Chapter 3 Additive Manufacturing Analysis

3.1 Introduction

3.1.1 Printer Interface Introduction

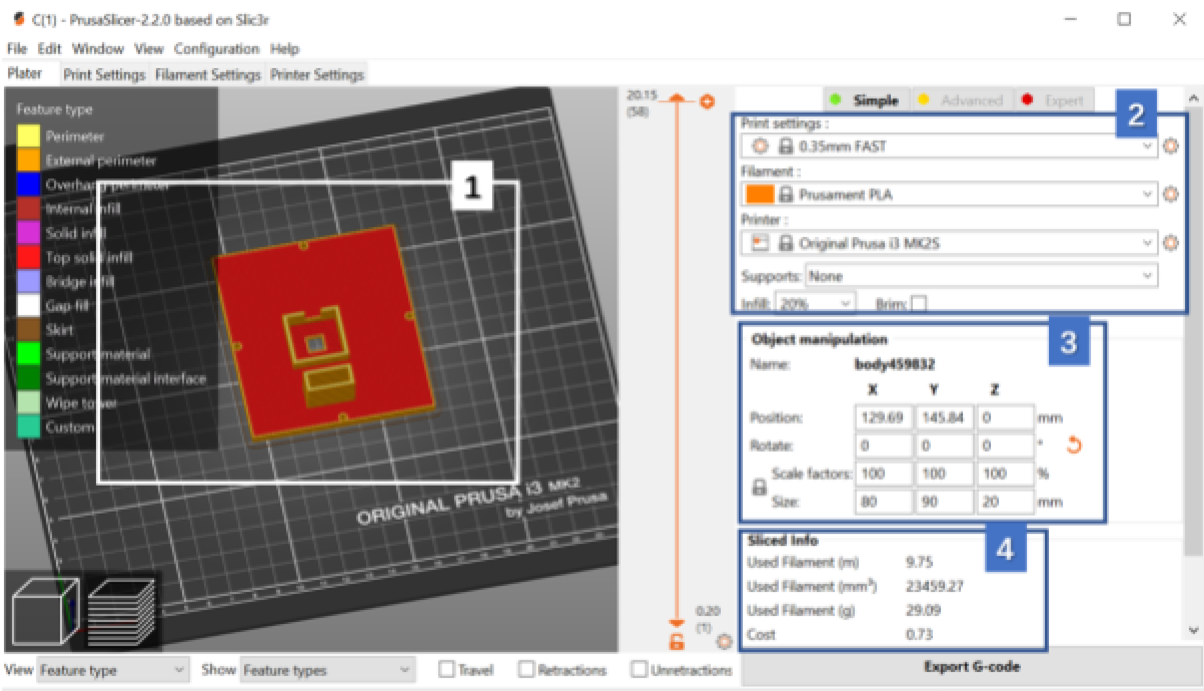


Figure 1-1. Printer Setting Interface

The software interface shown in Figure has four part: Part (1) is print model ‘real-scene simulation’, which can be used to check the filament stack of each layer and infill structure; part (2) is used for ‘parameter setting’; part (3) is for ‘model manipulation’ where the size of sliced models’ dimension can be scaled, and part (4) is ‘sliced model information’.

In the real-scene simulation the .amf file is imported, placed in the right location and sliced. The printing details can be set and adjusted in the right interface section. The default infill setting is 20% which is ideal for printing for most structures.

3.1.2 Model information

The following table shows the parameter setting and information of the ‘Isolation shelf’, ‘Trailer’, and ‘Water Tank’.

The printed parts’ weight is also taken into consideration for the design and printing process. As the dynamic excitation of the robot car is certainly determined by the motor speed of the robot car, which is set in Arduino code. Which means the increase of weight will lead to the longer deceleration distance of the robot car during obstacle avoidance. The actual obstacle avoidance testing process of the robot car also confirmed this speculation.

Table -1: 3D Printing Information Summary

<table>
<tr><th colspan="2">Model Name</th><th>Infill (%)</th><th>Infill shape</th><th>Filament width(mm)</th><th>Method</th><th>Time</th><th>Weight(g)</th></tr>
<tr><td rowspan="3">Isolation shelf</td><td>Top plate</td><td>10%</td><td rowspan="3">Rectangular</td><td rowspan="3">0.35</td><td rowspan="3">FAST</td><td>1h15m</td><td>26.9</td></tr>
<tr><td>Storeroom</td><td rowspan="4">20%</td><td>3h4m</td><td>70.5</td></tr>
<tr><td>Bottom Frame</td><td>3h20m</td><td>72.6</td></tr>
<tr><td rowspan="6">Trailer</td><td>wheel</td><td>Concentric</td><td>0.10</td><td>DETAIL</td><td>33m</td><td>4.2</td></tr>
<tr><td>Panel</td><td>Triangular</td><td>0.20</td><td>NORMAL</td><td>2h52m</td><td>40.1</td></tr>
<tr><td>Shaft</td><td>50%</td><td rowspan="4">Triangular + Concentric</td><td rowspan="4">0.10</td><td rowspan="4">DETAIL</td><td>1h2m</td><td>2.3</td></tr>
<tr><td rowspan="3">Shaft (experiment use)</td><td>20%</td><td>50m</td><td>1.9</td></tr>
<tr><td>80%</td><td>1h18m</td><td>2.7</td></tr>
<tr><td>90%</td><td>1h22m</td><td>2.9</td></tr>
<tr><td rowspan="2">Water Tank</td><td>Tank</td><td rowspan="2">20%</td><td rowspan="2">Concentric</td><td rowspan="2">0.35</td><td rowspan="2">FAST</td><td>1h59m</td><td>50.1</td></tr>
<tr><td>Tank Holder</td><td>2h1m</td><td>44.4</td></tr>
</table>

3.1.3 Infill Setting Comparison

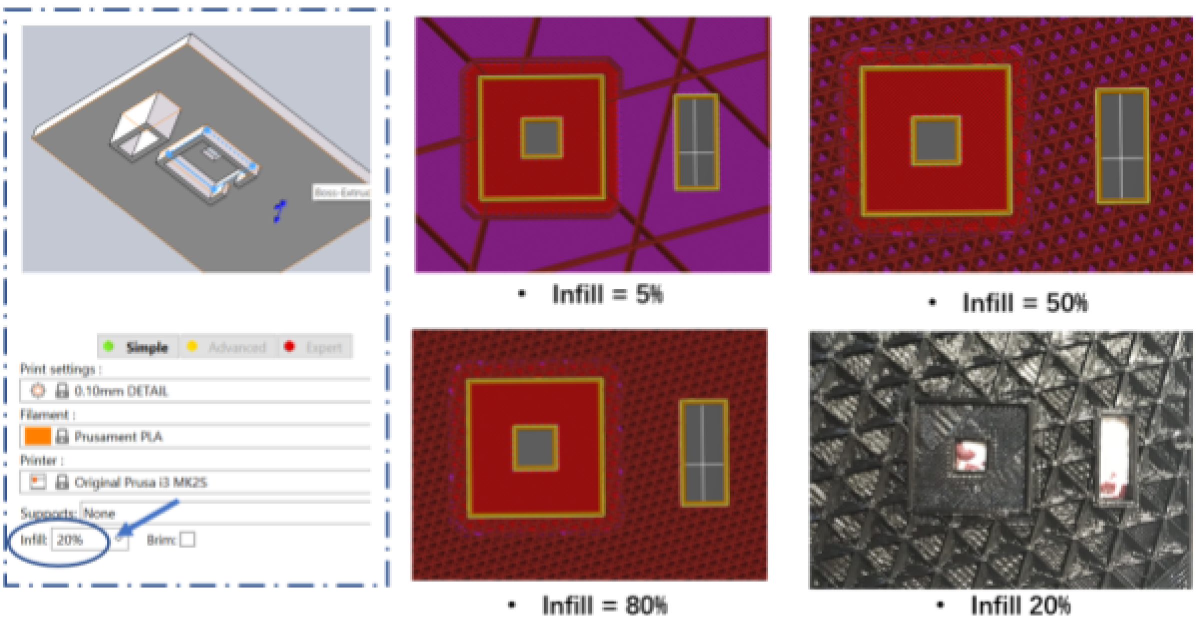


Figure 1-1. Infill Setting, Simulation and Comparison

The figure above shows the example of sliced model ‘Top plate’. The infill pattern is triangular, which is the strongest infill pattern because triangles are the strongest shape. They are least likely to deform and provide the best support structure behind the walls of the part. From the simulation results, the defaulted 20% infill is used for this model printing.

3.2 Structural Experiments

3.2.1 Equipment Introduction

The goal of testing the shafts' deformation along with force applied to certain position which corresponding to the trailer force Appling points. to make sure that the wheel height is well designed with certain space left for deformation and shaft with certain infill.

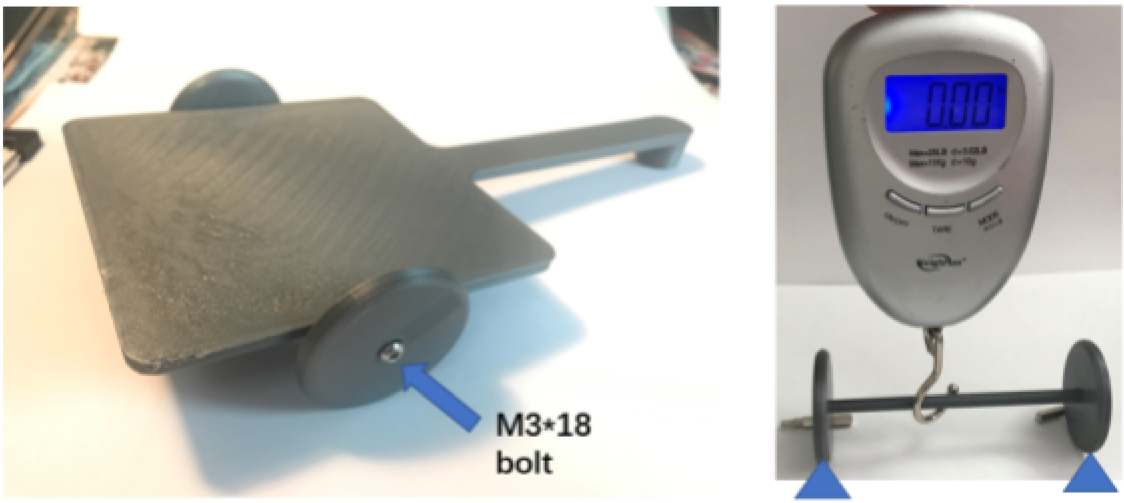


Figure 1-1. Trailer(left); Force Dynamometer

3.2.2 Experiment Diagram

The system designed for designed structural experiments is as the figure shows, the force is applied to one end of the shafts and we measure the deformation. The different infill percentage shafts (20%, 50%, 80%, 90%) with length equal to 90mm are used for force-deformation testing. From the experimental diagram, half of the shafts are fixed onto a desk. Certain forces (0.25kg, 0.50kg) afforded by force dynamometer are applied on the shaft's free end. Vernier caliper is also fixed to the desk to measure the certain position's deformation.

The experimental results are simplified into linear curves, from which, the deformation decreases along with the infill increases. Finally, according to the figure, the infill = 50% and 80% shaft are used for the trailer.

The mechanical testing of destructive structures is applied to the shafts at the end of the testing process. We chose infill to be 50% of the axle fracture uneven distribution, proving that the PLA material has a certain elasticity, and the adhesion coefficient cannot be completely unified in the stacking process of printed stick structure.

The structure around the fracture presents the phenomenon of deformation, bending and stretching. The large deformation proves that when the axle is close to the critical point of fracture, its structure has plastic change and absorbs external energy. Through deformation experiment and fracture experiment, we understand the variation characteristics of PLA columnar structure under stress, and get the result.

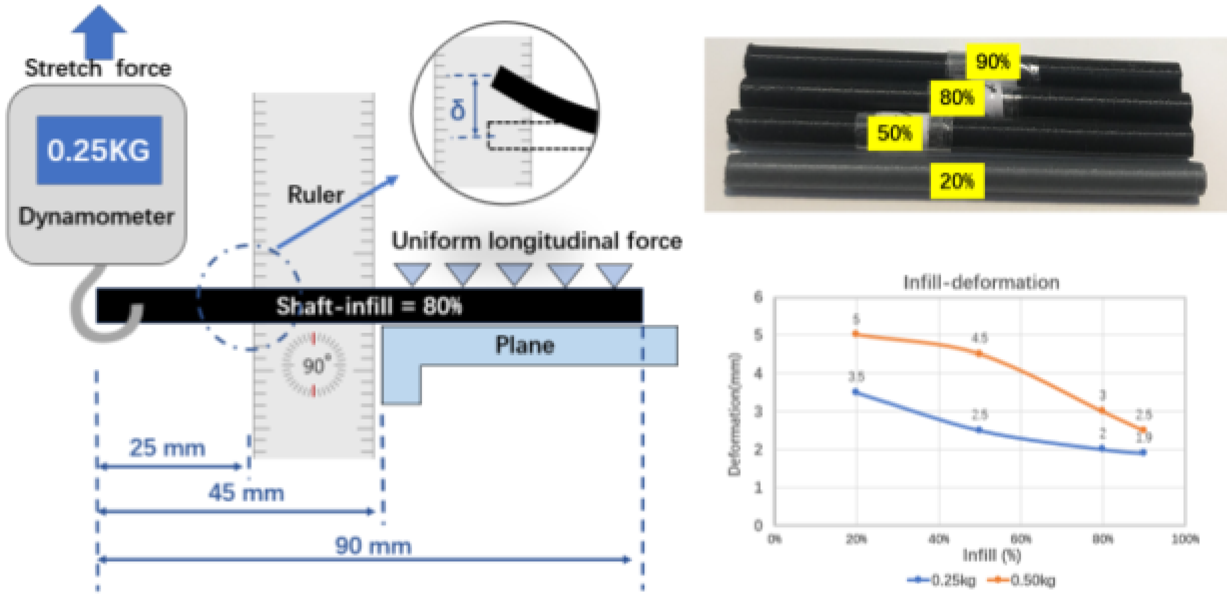


Figure 1-1. Experimental Diagram (left); Shaft with different infill (up right); Deformation Curve (down right)

3.3 Analysis of Parameters Influencing Printing Efficiency

3.3.1 Parameters in Additive Manufacturing.

This section covers the investigation of the effects of process parameters and their interactions on as-built part quality and printing-efficiency of the FDM 3D printing process. Under the practical circumstance, the parameters including infill percentage, layer thickness, printing speed, printing temperature, model complexity and surface inclination angle will influence both the dimensional accuracy, surface finishing of the printed workpiece, and the energy consumption and productivity of the printing process.

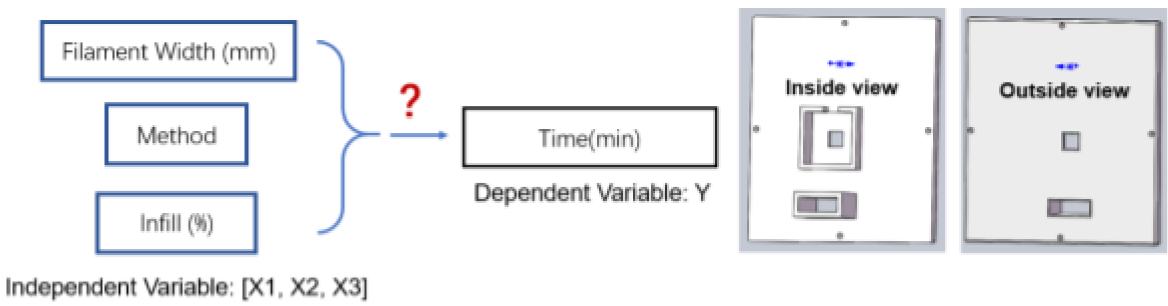


Figure 1-1. Independent and Dependent Variable Set Up(left); Model View(right)

In this report, the influences of three process parameters are taken into consideration in particular: filament width, method and infill percentage. By using the printing data of the top plate model simulated by printer, the linear regression expression of the interaction of various parameters on the printing efficiency is given, which predict the printing time for this top plate model. At the same time, through the calculation of Pearson correlation coefficient, the different parameters' correlation with printing efficiency(time) was obtained. The data is showed in Figure below.

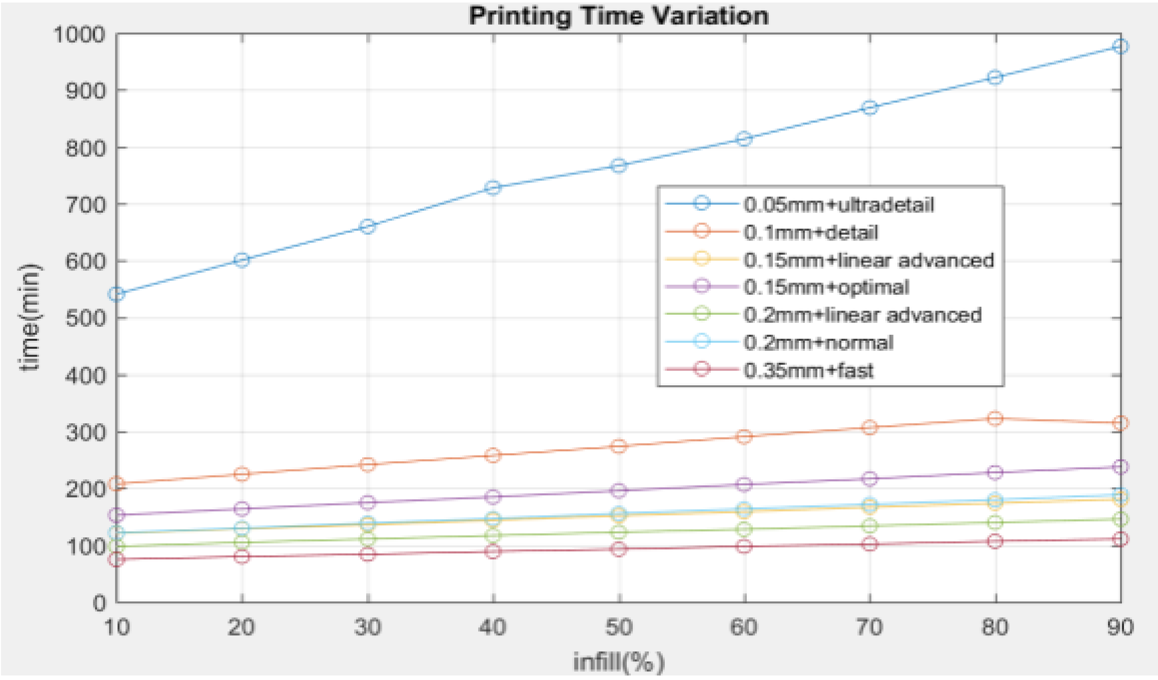


Figure 1-1. Data Extracted from Simulation

3.3.2 Linear Regression for Time Prediction

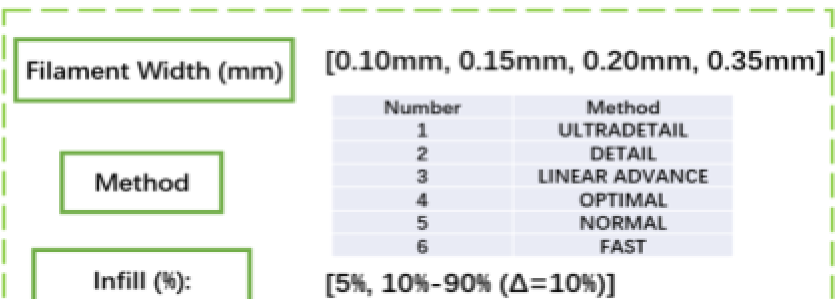
Regression analysis [1-3] is used to study the influence relationship between X (quantitative or categorical) and Y(quantitative), whether there is an influence relationship, how the influence direction and degree are. In this case, the parameters work as X: X1-filament width, X2-method, X3-infill percentage, and printing time as Y. The following shows the processing steps:

1) the model fitting situation is firstly analyzed, that is, the model fitting situation can be analyzed by r-square value, and VIF value can be analyzed to determine whether there is a collinearity problem in the model (Collinearity problem can be solved by ridge regression or stepwise regression)

2) analyze the significance of X; If it is significant ($P < 0.05$ or 0.01); Then it shows that X has an influence on Y, and then analyze the direction of the influence relationship in detail.

3) the degree of influence of X on Y (optional) is analyzed by combining the regression coefficient B value.

4) summarize the analysis and give the expression.



As can be seen from the table, they use *'filament width', 'infill', 'method'* as independent variables and *'time'* as dependent variables for linear regression analysis. the model R square value is 0.579, which means the filament width, Infill, method(number) can explain the reason for the 57.9% change in time.

Table 2: Parameter Estimates

Parameter Estimates (n=50)									
	Unstandardized Coefficients		Standardized Coefficients	t	p	VIF	R^2	Adj R^2	F
	B	Std. Error	Beta						
Constant	494.241	67.538	-	7.318	0*	-	0.579	0.551	F (3,46) =21.049, p=0.000
filament width	-635.714	575.412	-0.251	-1.105	0.275	5.635			
infill	2.249	1.048	0.206	2.146	0.037*	1.003			
Method (number)	-67.744	31.732	-0.485	-2.135	0.038*	5.638			
Dependent Variable: time									
D-W: 1.432									
* p<0.05 ** p<0.01									

The connected width, Infill and method(number) of the model have an influence on time, and the formula of the model is as follows:

$$time = 494.241 - 635.714 * filament\ width + 2.249 * Infill - 67.744 * method.$$

They have also been verified by F test (F=21.049, P =0.000<0.05). In addition, the test of the model's multicollinearity found that VIF value in the model was greater than 5 but less than 10, indicating that there might be some collinearity problem.

At the same time, it is suggested to check the independent variables with a close correlation, and then make a new analysis after eliminating the independent variables with a close correlation. According to the final analysis, the filament width has a regression coefficient value of -635.714(t=-1.105, p=0.275>0.05), which means the filament width does not have an influence on time. The regression coefficient value of 'Infill' was 2.249(T =2.146, P =0.037<0.05), indicating that 'Infill' would produce time

3.3.3 Correlation Analysis

Correlation analysis [4-7] is used to study the relationship between quantitative data, whether there is a relationship and the degree of closeness in between. The analytical steps are as following:

1) specifically analyze the relationship between each Y and each X, and whether there is a significant relationship between Y and X.
2) Then analyze the correlation is positive or negative; The correlation coefficient can also be used to describe the degree of closeness;
3) summarize the analysis.

Before correlation analysis, the scatter diagram can be used to observe and show the correlation between data, or the normal diagram can be used to observe and show the normal distribution of data. The result of relationship is showed below in Figure. (a) shows the parameters coefficient in the expression of time prediction. (b) shows the examples of scatter diagrams with different values of correlation coefficient (ρ) and (c) shows the Pearse correlation coefficient of parameters.

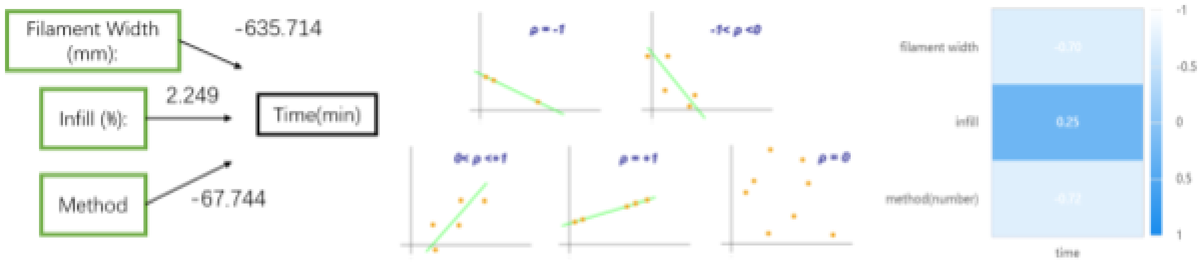


Figure 1-1. Parameter Relationship in Time Prediction Expression(left); Examples of Different Pearson Correlation Coefficients (ρ) (middle); Pearson Correlation Relationship (Right)

3.4 Dynamics Simulation Using FEA Method

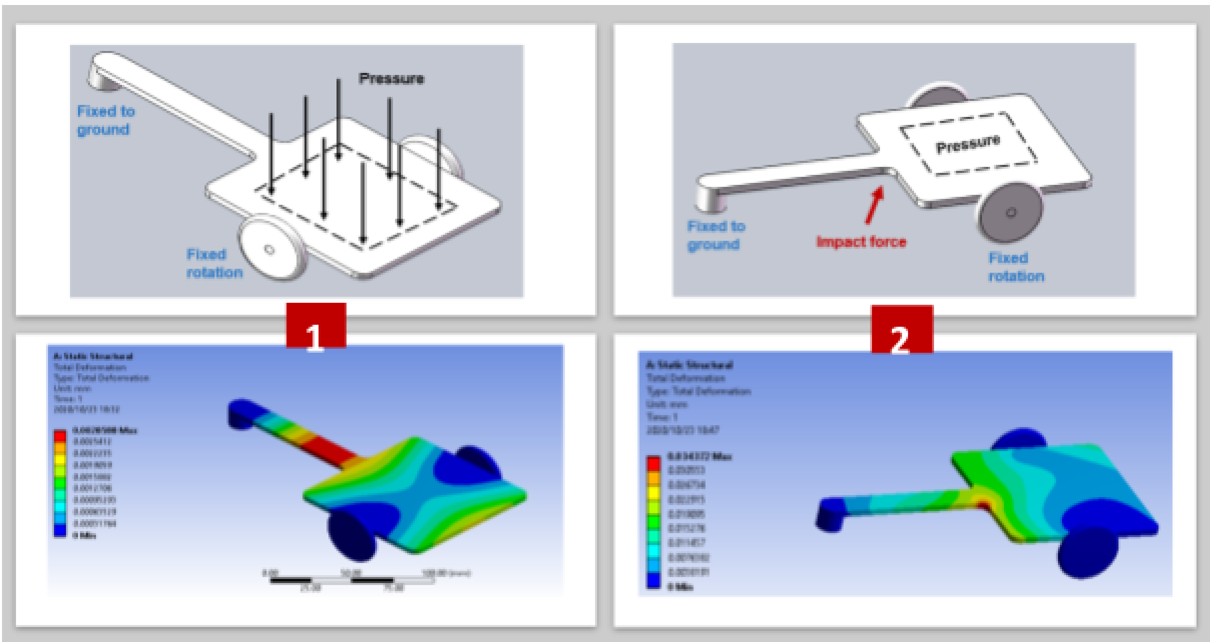


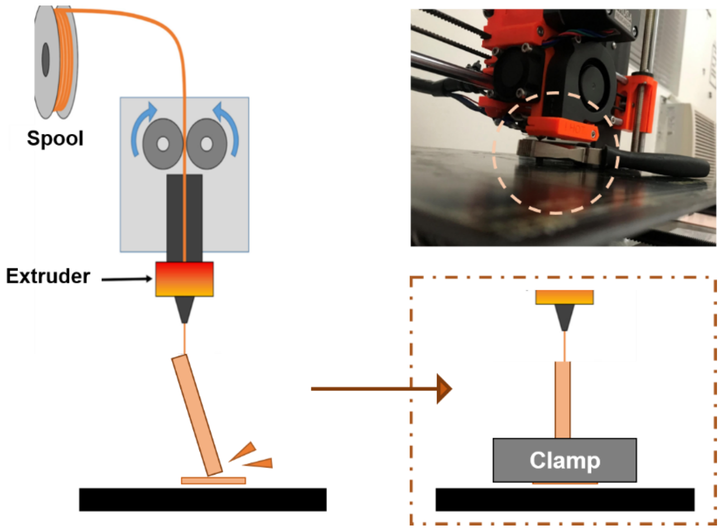
Figure 1-1. Pressure Applied (1); Pressure + Impact Force Applied (2)

The ANSYS Static Structural Module are used for the trailer model's FEA simulation. The goal for FEA is to show the Overall stress distribution of our trailer. This figure shows two different results of stress loading analysis.

Chapter 4 Design Problems and Optimizations

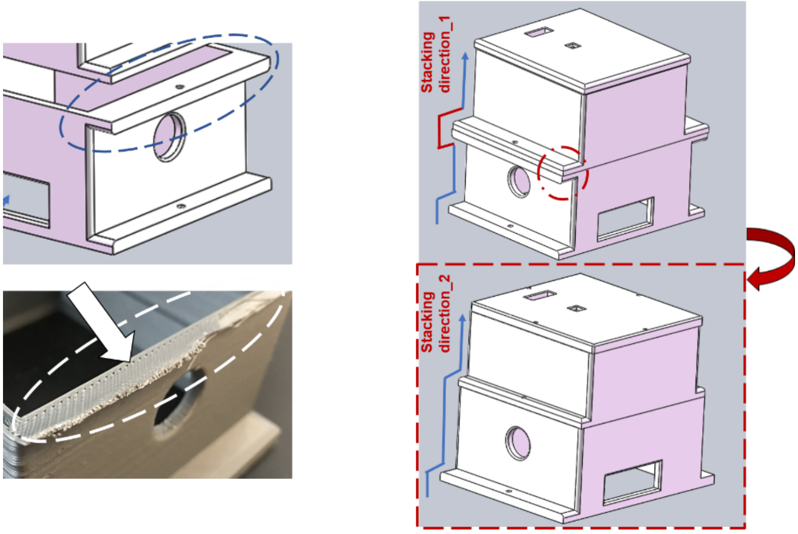
4.1 3D Printing Problem 1

When building parts, some problems regarding 3D printing occurred. Since support materials were not used when building parts, when printing the axle of the wheels, the axle is likely to break at the bottom. To deal with it, a clamp was used to fix the part on the part bed to be printed well.



4.2 3D Printing Problem 2

Since support materials were not used when building parts, parts were not able to be built with stair stepping. Thus, the parts were redesigned to be printed well without support materials.



Chapter 5 Conclusion and Future Work

Suspension System

⇕

Integrated design

⇕

More Feature

Suspensions

Sweeping Machine

References

[1] The SPSSAU project (2020). SPSSAU. (Version 20.0)[Online Application Software]. Retrieved from https://www.spssau.com.

[2] Hauke J, Kossowski T. Comparison of Values of Pearson's and Spearman's Correlation Coefficients on the Same Sets of Data[J]. Quaestiones Geographicae, 2011, 30(2):87-93.

[3] Arndt S, Turvey C, Andreasen N C. Correlating and predicting psychiatric symptom ratings: Spearmans r versus Kendalls tau correlation[J]. Journal of Psychiatric Research, 1999, 33(2):97-104.

[4] The SPSSAU project (2020). SPSSAU. (Version 20.0)[Online Application Software]. Retrieved from https://www.spssau.com.

[5] Sun Dao-de. Selection of the Linear Regression Model According to the Parameter Estimation[J]. Wuhan University Journal of Natural Sciences, 2000, 5(4):400-405.

[6] Barassi M R. Microeconometrics; Methods and Applications by A. Colin Cameron; Pravin K. Trivedi[J]. 2005.

[7] https://en.wikipedia.org/wiki/Pearson_correlation_coefficient