3D Metal Printer

Design Document

October 2018 - Team 3

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Table of Contents

List of figures/tables/symbols/definitions

Figures[2]

1.1 Acknowledgement

Dr. Timothy Bigelow, Associate Professor of Electrical and computer Engineering at Iowa State, serves as the faculty advisor for this project. He provides guidance, technical advice, and design constraints in our weekly Thursday meetings. The funding for this project is from a research grant that Dr. Bigelow obtained. His support and guidance will help ensure the completion of the project.

1.2 Problem and Project Statement

This senior design team is tasked with completing a Metal 3D Printer with safety systems. This is phase two of the Metal 3D Printer. The main body of the printer has been built. Our task for phase two is to design and build the roller, calibrate the stepper motors, complete vacuum sealed container, test printer with the roller in vacuum container, testing safety systems, and building a CAD drawing with the 3D printer. The safety systems are systems that make sure the printer is operating in a safe temperature to produce CAD drawings and preventing harm from the pure nitrogen gas environment. Components included in the safety systems are cameras, temperature sensors, and barometer.

To complete this project, we first plan on designing the roller with a stepper motor. This roller is very important for laying out the metal powder for the metal printing. As the roller is being designed, the safety systems will have the components researched for the appropriate function and cost. That would include the camera's, temperature sensors and the barometer. The sealed container will be tested for a proper nitrogen environment with no oxygen gas present. All three of those components will be programmed together to go to the last stage of testing. The last stage of testing will be testing the roller and see if it can complete an accurate 3D CAD drawing. The printer will be monitored at all times by the camera and by the sensors to ensure the printer is still functioning and can operate at the appropriate temperature.

The team plans to complete the 3D printer that was explained above. With it completed, the 3D printer can be used for researchers to create simple objects safely and effectively.

1.3 Operational Environment

The operating environment for the printer will be in a laboratory setting. The laser requires a specific environment as well. The printer needs to be sealed in a chamber filled with nitrogen or argon gas to evacuate all the oxygen. If the chamber leaks, there may be risk of of suffocating people in the room as well as the laser not functioning properly. We will be communicating with EHS at Iowa State to ensure that all the proper safety measures are being taken to keep the users safe.

1.4 Intended Users and uses

The intended end users of our printer are researchers in the area of nondestructive evaluation and materials. They will use this printer to produce and evaluate several simple shapes.

This printer will be used for research purposes, it must be able to be adapted and easy operation. In other words, the technical portions of this project is to have very well documentation to adapt the code for future projects. Hence, it is not supposed to be a sealed, non modifiable, end consumer product. This means that the end users should be kept in mind for the hardware and programming language used. Most likely, none of the researchers using the printer will not be software engineers so simple and well documented Java or Python code would be preferable to make efficient and easy use for the researchers.

1.5 Assumptions and Limitations

Assumptions

The project is to develop a 3D Metal Printer that uses a laser based nondestructive evaluation system for monitoring of additive manufactured parts. Thus, the build speed and complexity of the printed parts is not a concern. The end product will not be used for commercial use but for research purposes.

Limitations

The budget for this project is approximated at $10,000. The end product will fiber-couple 3 lasers to focus on the same spot. The three lasers (client requirement) will be 200 watt fiber lasers (spi lasers), Nd:YAG laser at 1064 nm wavelength, 50 mJ (Quantel), at 20 Hz; and the last laser will be a laser interferometer (OPTECH) at 1550 nm wavelength, 50 mW. The fiber-coupled laser will be housed in an optical head and would need to be in a vacuum chamber of 10^{-3} to 10^{-6} torr. Dust protection from the powder bed will be needed.

1.6 Expected End Product and Deliverables

The end product will provide researches the access to analyze additive manufactured parts. The mechanical design of the 3D printer includes five steppers motors for the powder bed, the roller, and the laser optical control head. The delivery date for the testing of the 3D printer, in the vacuum container, will be at the end of the first semester of Senior Design. The second semester will include the final testing of creating CAD drawings. If there is extra time, eddy's currents may be added to the safety systems for monitoring.

In addition, a sensor system will be used for the overall safety requirements. The sensor system will be comprised of an external oxygen sensor, an internal oxygen sensor, temperature sensors, and a barometer. The external oxygen sensor will be a device that will warn the user if the oxygen levels are not sufficient in the room. The internal oxygen sensor and barometer will be an Arduino based system that will allow the users to monitor the oxygen and pressure within the chamber of the 3D metal printer. The temperature sensors will be used to measure the inside temperature and outside temperature of the sealed container. This is to ensure that the container is not too hot to touch and that the printed CAD drawing is printing properly. This system shall be expected to be finished at the end of the first semester of Senior Design.

2. Specifications and Analysis

Since we are working on part two of the project, many of the parts have already been ordered and the printer has been mostly assembled. The plan of the last group was to use a mechanically controlled laser head to print along with two lasers, one ultrasound and one interferometer, to perform non-destructive evaluation while the printer is working. The design is currently able to draw a 2D design, and our goal is to implement a roller for the metal powder and design the software to allow for full 3D printing.

2.1 Proposed Design

Since the project has already been partially completed, we have very clear goals for the project. The physical design of the printer is almost complete, and we need to add a roller for the metal powder as well as install the three lasers. A figure showing the final physical design of the printer is included below. We also hope to control the printer using the provided PC through a serial connection. Finally, we will expand the software interface to allow expansion to 3D printing from 2D printing. The second figure below shows how we plan to implement the user interface as well as the interaction between the software and hardware.

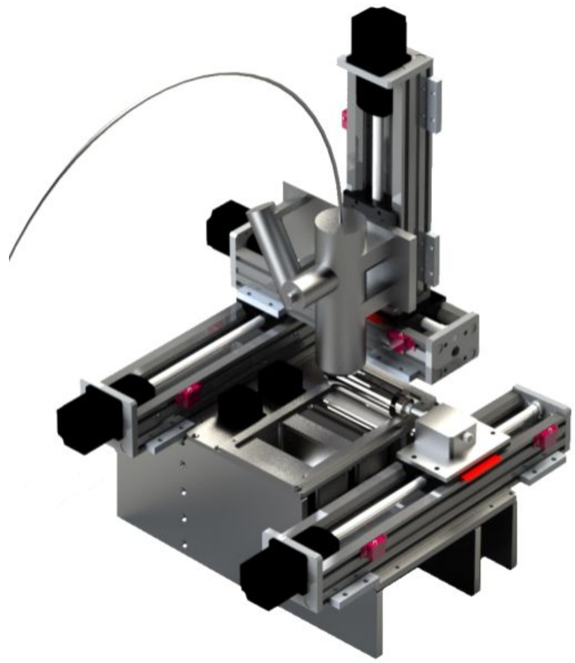

Figure 1, Rendering of final 3D printer

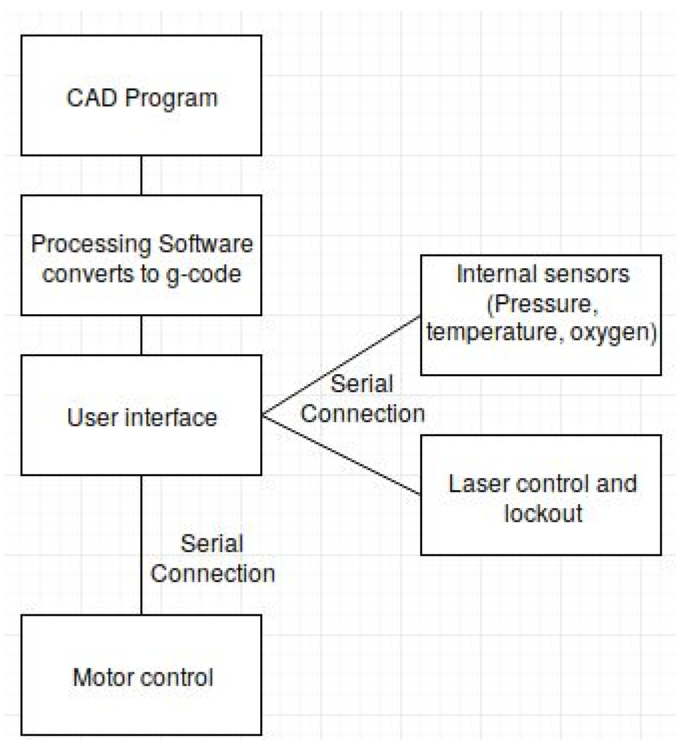

Figure 2, Block diagram of software and hardware interaction

2.2 Design Analysis

There are several large safety concerns for this printer. Since the printer needs to be atmospherically controlled, keeping a sealed container is a concern. There is another cause of concern with the class 4 lasers, which have serious radiation and exposure hazards. Both of these issues will be controlled by the container that the printer will be housed in. This is good because it keeps the printer in an isolated environment, but any leak will push oxygen out of a room as it gets filled with pure gas. It is critical for us to use a safe container due to this.

The other two designed components, the roller and the dispenser have no safety concerns. The roller needs to be made of a material that does not allow for sticking of the aluminum powder to the roller. The dispenser needs to constantly output an evenly dispersed layer of powder. The roller will also push down the layer of powder after it is dispensed, to minimize air gaps in the metal. The Roller design is shown here, in Figure 3.

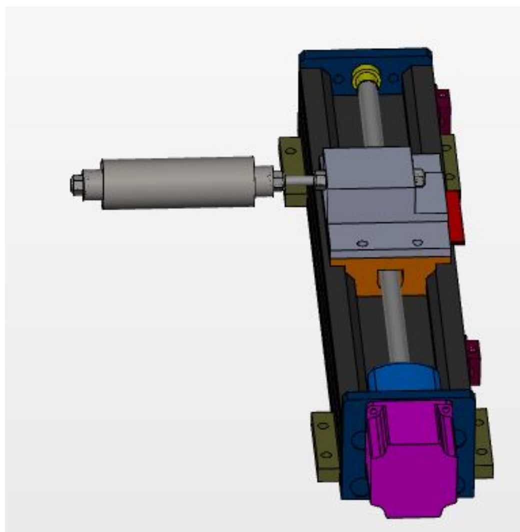

Figure 3: Design of the roller assembly

The print bed, on which the roller will function, has gone through several stages of design. The bed needs to remain flush with the walls, as well as be able to travel up and down using stepper motors. The final design for the print bed is included in the figure below. There is a powder collection bin directly adjacent to the print bed, for the roller to push all excess powder into for recollection. The design for this is shown in Figure 4, below.

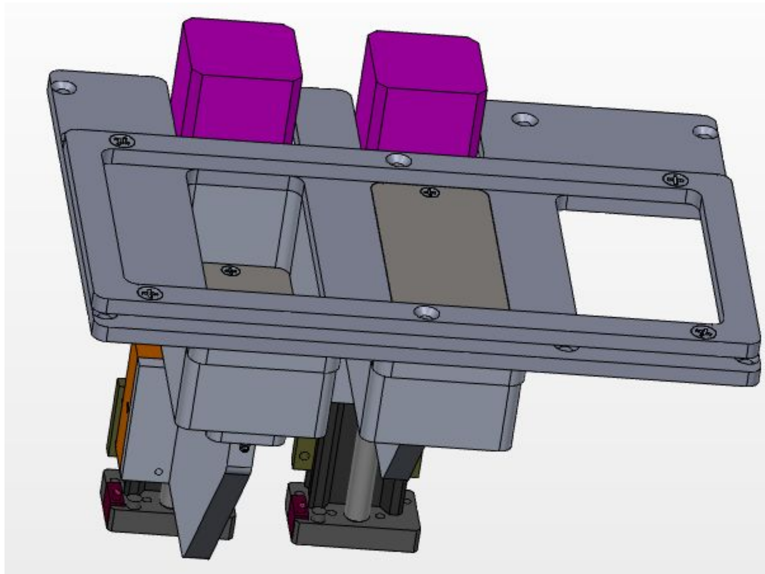

Figure 4: Print and powder bed design

The plan for depositing the powder is to have two stepper motors which will control the print bed and the powder bed. With each layer of powder deposited and melted, the print bed will move slightly down and the powder bed will move slightly up. The roller will then roll over the powder bed, collecting powder as it does. The roller will then roll over the print bed, depositing a thin layer of powder on top of the previous sintered metal. Finally, the roller will roll back, the powder will be melted, and the process will repeat. The figure below shows a visual representation of how the powder depositing process will work.

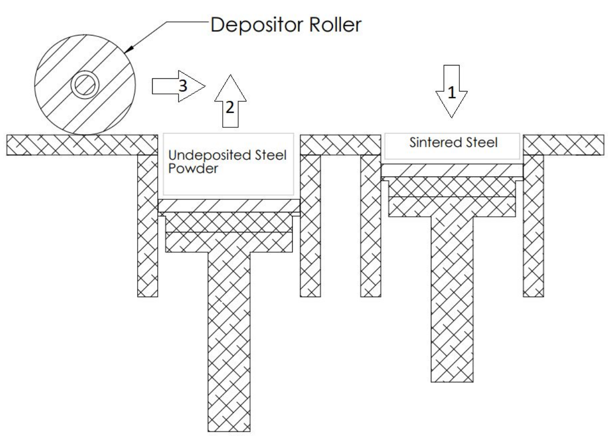

Figure 5: Representation of how the roller will deposit powder

This is the final design, of which most has been implemented. The print bed and dispenser need to be manufactured, which should be done soon. There is no other components of the printer that we need to design, our next step is implementation and testing.

3 Testing and Implementation

For this project there will need to be a significant amount of testing before the project will be approved. Before testing the system as a whole, each aspect of the project will need to be test. Both the software aspects and the actual machine needs to be tested. Some of the functional items that need to be tested include the laser-guiding stepper motor, oxygen sensor, powder system, laser, software interface, oxygen alarm, and cameras. Some of the nonfunctional items that need to be tested include, the speed of printing, print accuracy, powder efficiency, temperature, and oxygen level.

3.1 Interface Specifications

Our testing interface will be done through a pc connection. We will use this interface to send commands to the machine and also use it to take input data from the sensors and cameras. We can then use the data to confirm that the sensors are functioning properly as well as the systems they are monitoring.

3.2 Hardware and software

The project uses an iowa state desktop computer that will be compiling and running gcode and C# programming languages. These programs will then be used to control stepper motors that will be moving a powder roller and a laser about it its axis to move and shape the metal powder to what we want. We will also be using various cameras and sensors to monitor the printing process so that we can make adjustments as needed. These include things like an oxygen and pressure sensor to make sure we maintain a vacuum. A temperature sensor to make sure nothing gets too hot from the laser and a camera so we can watch the process of moving the powder and laser inside of the closed environment.

3.3 Process

The process of testing the printer will be done by using our various sensors and cameras to monitor the system as it runs and make sure everything is looking the way it should be. The motors should be moving the roller and laser the correct distance which will be tested by using measurements and the video from a camera. The oxygen sensor should show none in its vacuum state, and the pressure should read low. The temperature sensor will be used for safety involving the box and the environment by ensuring things do not get too hot. Finally the printed result will also need to be what was intended and should match the design that was sent to the printer.

3.4 Results

So far we have not done any testing as we are still in the process of assembling the printer. As of now the motors are working and we are able to move a placeholder pencil that will later be replaced by the lasers. We also have all the sensors we need but have not yet implemented their use.

4 Closing Material

4.1 Conclusion

Our project is to complete the 3D Metal Printer for Dr.Bigelow. Our goals for the project is to finish up phase two of the 3D printer. By the end of this semester, our goal is to have the printer to run and communicate with the software. Ideally we want to start testing by the beginning of the second semester. This means we have to be done designing the safety concerns including the placement of oxygen sensor, temperature sensor, contact sensor, and cameras. Our plan to achieve this goal is to work together as a team throughout the entire project, have consistent weekly meetings as a group as well as with Dr. Bigelow, and always contributing to the sharing of ideas and problems. The printer will be controlled by a pc where to pc will send instructions to a set of stepper motors and the powder system that will be laying out the stainless steel powder. Another computer will be used for sensor data and cameras to monitor the printer and making sure it is safe throughout the process. Some of our biggest challenges include the safety of laser, the limitations of the interferometer, limitations of the camera due to temperature and pressure, and the preciseness of the laser.

4.2 References

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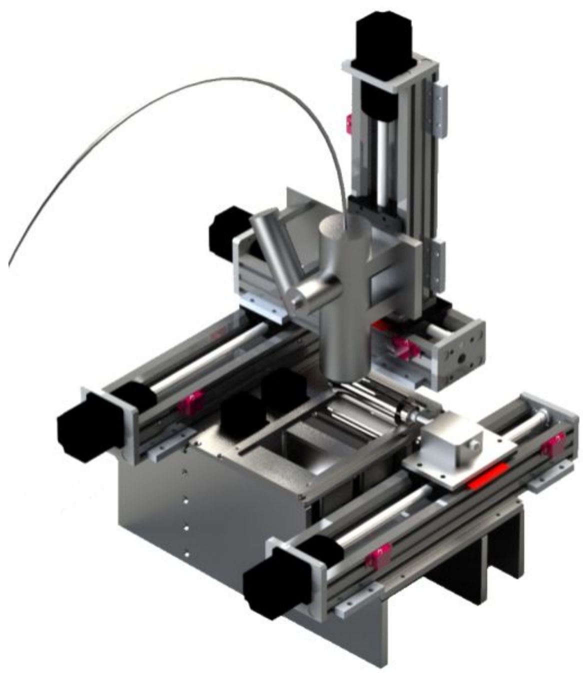
4.3 Appendices



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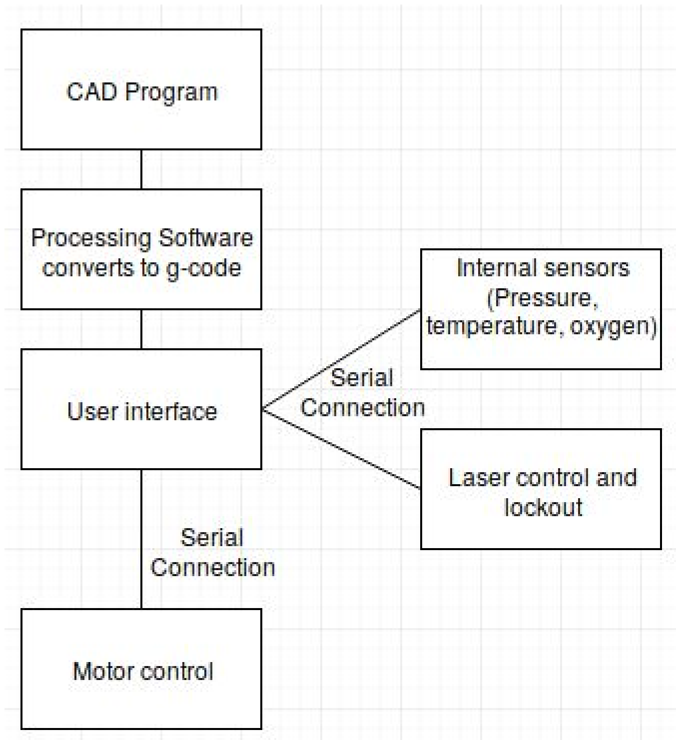

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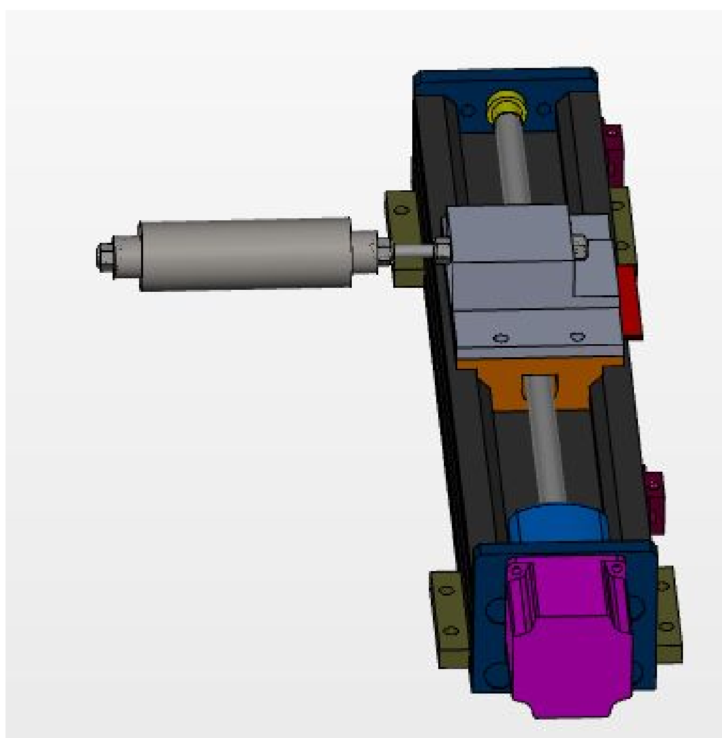

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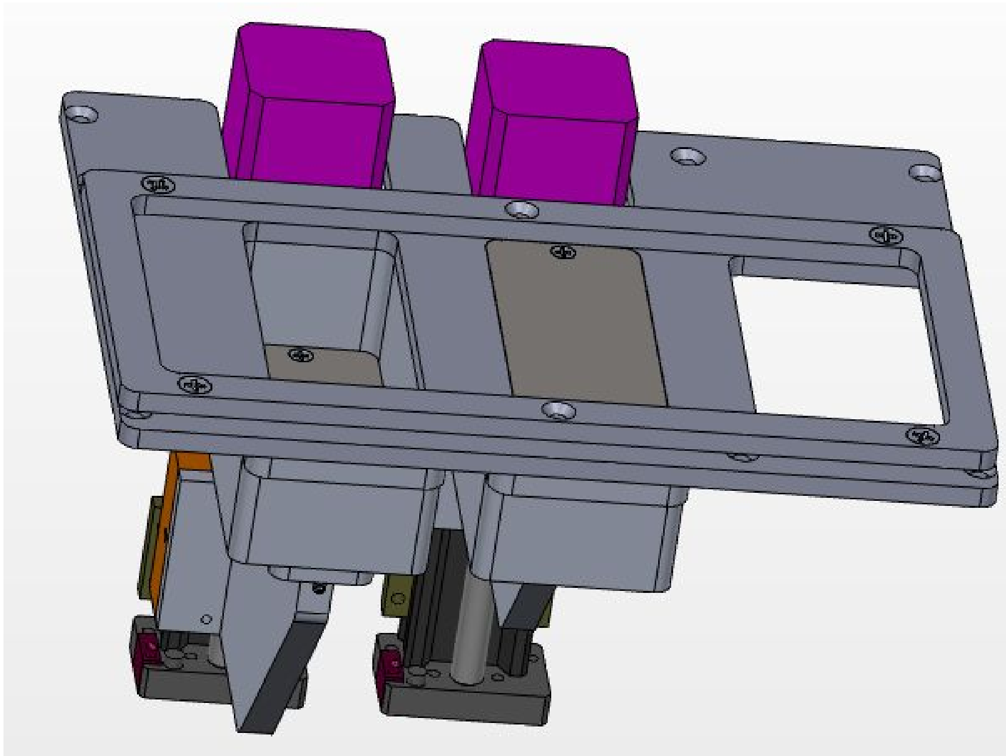

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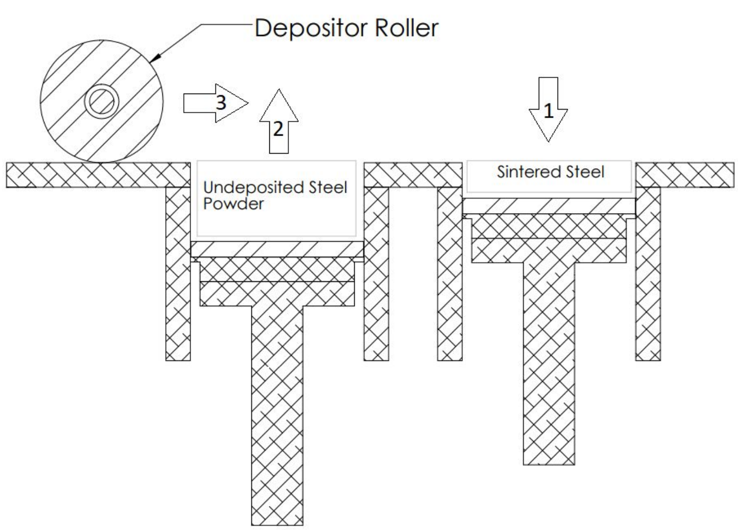

Figure 5: Representation of how the roller will deposit powder