3D Metal Printer

PROJECT PLAN

September 2018 - Team 3

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1 Introduction

1.1 Project statement

Our team is tasked with continuing the creation of a 3D metal printer. The scope of the project includes creating a printer which melts metal powder using lasers to create objects. We are also tasked with choosing and implementing sensors to track the operation of the machine including a camera, eddy current sensors, and temperature and pressure sensors.

1.2 Purpose

The most important function of this design is currently to create a simple cube. The way that this is done can be broken up into three steps. First, there will be a roller which rolls out a thin sheet of metal powder. Once the powder is rolled out, a set of lasers will melt the metal in order to make the shape wanted. The entire process will then repeat with another layer until the object is created.

1.3 Goals

Our main goal at this point in time is to create a functioning 3D metal printer which is able to create a cube. We also hope to implement a camera in order to monitor the creation of objects, as well as temperature and pressure sensors to make sure that the environment remains oxygen-free and that the printer is not putting out too much heat. We also hope to have eddy current sensors implemented.

2 Deliverables

Deliverable	Description
Physical Printer	The CAD design of the printer was created and the physical printer was started by the previous group working on this project. Our goal is to complete the physical design of the printer using these design files
Software interface	There should be some way to interface with the printer without having to directly create code for the motors. We will create a program that will convert CAD files into code which can be fed into the printer.
Safety System	The main goal of the project is to ensure safety and monitor any possible safety issues. The safety issues we will be monitoring the most closely are the temperature of the printer and environmental box, the radiation from the printer, and the oxygen content inside of the vacuum, which should be zero.
Quality monitoring	Our team will implement other sensors in order to monitor the quality of the objects being printed. Some possible sensors which we will use to monitor are eddy current sensors and infrared cameras to ensure even heating on the object.
Embedded system	The printer will be operated using a laptop or desktop computer. There will be alerts connected to the computer concerning the safety system and quality monitoring.

3 Design

3.1 Previous work/literature

Additive manufacturing (AM) is a process through which 3D printing can be done with materials which are harder to work with or to create shapes which cannot be created through other methods. Additive manufacturing is done by creating an object a single layer at a time. There is a small amount of material rolled out, and then the shape of the object wanted is created. This method creates much less waste than other methods of manufacturing, and allows for much more flexibility in building prototypes by allowing dynamic production (Brand 2017).
Additive manufacturing technology is quickly growing in both the consumer and corporate spheres, and the market for AM is expected to grow from $4 billion in 2014 to $21 billion by 2020 (Thompson et al 2016). Because of the explosive growth of AM technology, there is a lack of generally accepted standards among the industry (Ghao et al 2015). This is also made difficult by the fact that there are so many different ways to go about completing a task using additive manufacturing, making it much harder to make one set of overarching standards. Another essential issue currently facing the world of additive manufacturing is that fact that there is a lack of quality assurance due to the fact that in-process monitoring during additive manufacturing is not up to par (Everton et al 2016). Due to this fact, companies are less likely to use additive manufacturing for expensive items or items where failure cannot be tolerated (Everton et al 2016). Although research has been expanding on in-situ monitoring of AM technology, the level of monitoring is still unacceptable for any critical parts. One organization on the forefront of this is NASA, which hopes to use non-destructive evaluation (NDE) for spacecrafts and instruments (Waller et al 2014).
While NDE is a good way to monitor additive manufacturing before, during, and after the printing process, there are still major gaps in NDE technology for additive manufacturing. Some examples of issues that NDE currently has are the monitoring of creation of complex geometric shapes and a lack of algorithms to automatically detect defects during the printing process (Waller et al 2014). Since complex geometry is one of the main attractions of additive manufacturing, and lack of waste is another, these are critical problems.
Despite the fact that there are no true standards for NDE and that the technology is lacking, additive manufacturing still has boundless opportunities for individuals and corporations. Some possible uses for additive manufacturing in the future are printing using multiple materials, creating objects based off of sketches, and even printing organs using human tissue (Brand 2017, Ghao et al 2015).

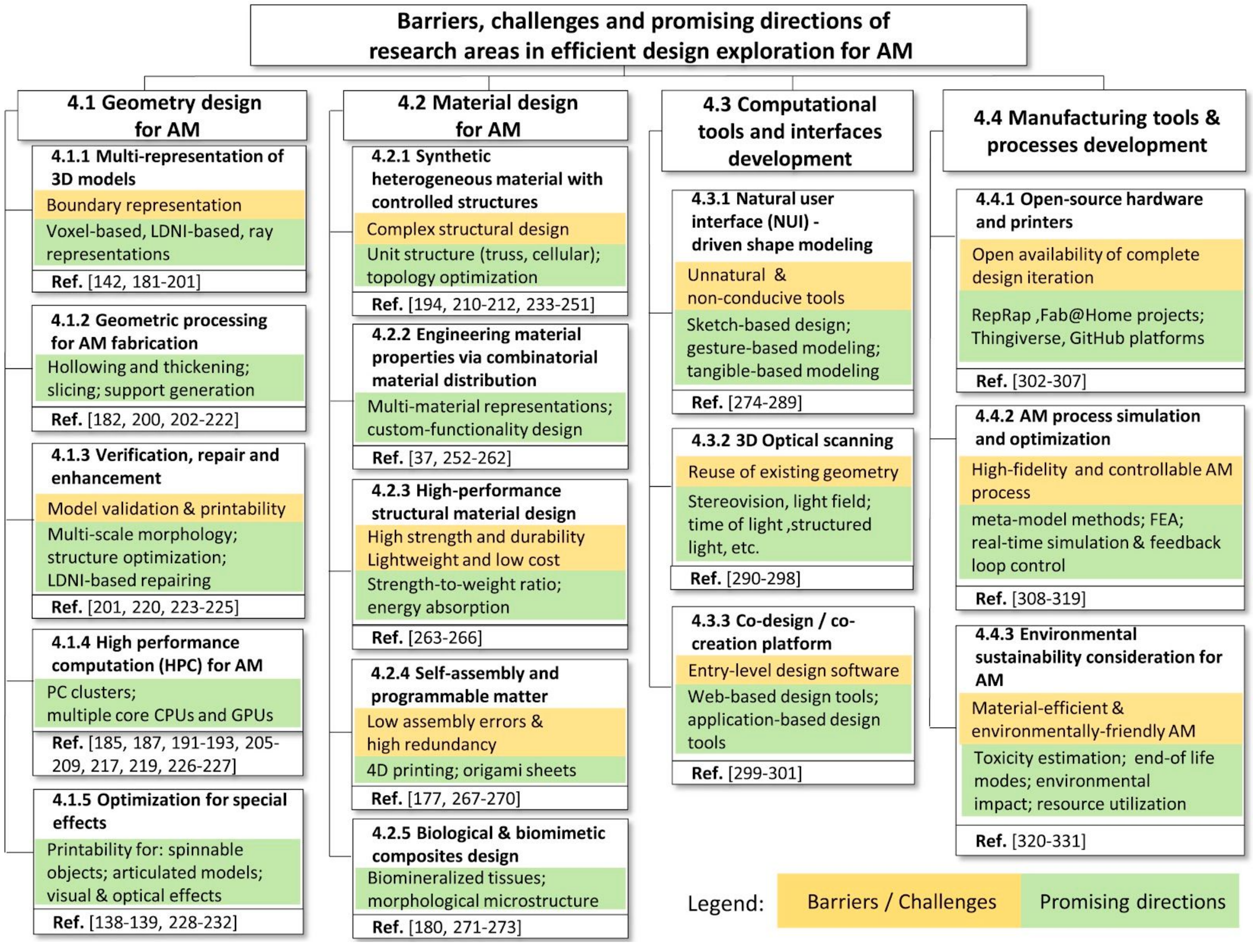

Figure 1: Possible applications and challenges coinciding with the growth of additive manufacturing (Ghao et al 2015).

3.2 Proposed System Block diagram

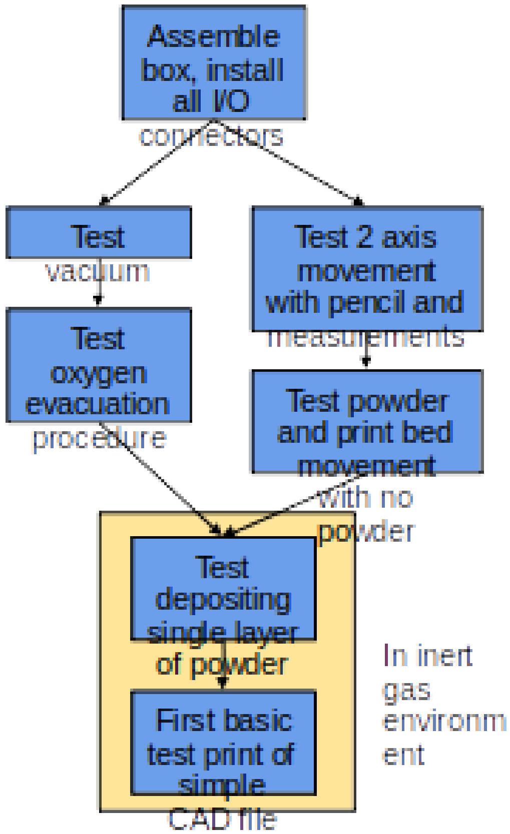

Figure 2: Block diagram of 3d Printer Phase II design

3.3 Assessment of Proposed methods

To make the workload even and efficient, the team discussed an option to accomplish this. The plan that was discussed was having three pairs. Each pair would include each major. So, there would be one pair of computer engineers, one pair of software engineers, and one pair of electrical engineers. We thought this would be beneficial so that the pairs could discuss between each other to generate ideas or solutions. Even though we are in pairs, we can come together as a group to check in or to help someone elses problem.

As shown above in Figure 2, our 3D printer was planned and discussed with our advisor, Dr. Bigelow. We will finish both the nitrogen/argon sealed container and the 3D metal printer. Each of those components then will be tested to properly test the sensors and the functionality of the componentents. After both components pass, then the two components can be built together. This means that the 3D metal printer will be placed inside the sealed container to test the laser and the layer of powder. If that test is successful, then the final step would be to convert CAD drawings into the printer and construct those drawings. This would be the true test to see if the printer can complete a task and to see if the CAD drawing is made correctly.

3.4 Validation

With the project on a budget, we will discuss the construction of the 3D printer with Dr. Bigelow. This would include the purchasing of camera, sensors, stepper motors, and other necessary components. Each component will go under testing to make sure each component can survive a vacuum and still operates under those conditions. This would include software to operate the components, which would attached or added on to produce a safe operating 3D metal printer. To assist with the mechanical side of the project, Dr. Bigelow hired some mechanical graduate students that will assist us with the mechanical components that need to be created.

The Software testing , will have multiple steps. The first step would be connecting and operating the metal printer from a computer. This will help establish that the code is working as well as the printer working. Next, would be programing the oxygen, pressure, and temperature sensor to either operate the printer or shut down the printer. Each sensor would be tested and debug in a vacuum sealed container to achieve the proper coding for functionality.

Hardware testing will be testing the two main components, the sealed container and the 3D metal printer. The sealed chamber will be tested for a nitrogen/argon environment. This would include the absence of oxygen in the sealed container. The 3D metal printer will be tested for the functionality of how it will operate the laser mount. The laser mount is used to position the laser in the proper spot for melting the powder, which is used to create the object. The laser mount will have to be tested for efficiency as well as functionality. This will require some debugging in the coding and calibrating the stepping motors. To test the laser mount outside of the vacuum, we will use a pen to draw out for where the pen is going. This will help us to visually see the operation of the laser mount so that we will be able to calibrate the laser mount properly.

The final testing would be testing the 3D metal printer in the sealed container. This will be the first test to see if the powder will be melted properly in the sealed container. Testing this will be a good way to make sure that the laser is working properly as well as the code for the laser mount. If the testing proves positive, then the last test would be printing a CAD drawing. This may have multiple problems but it would provide sufficient information about what needs to be fixed.

4 Project Requirements/Specifications

4.1 functional

- The printer shall have 3 lasers- a 1064 nm 200 W melt laser, a 1064 nm ultrasound generating laser, and a 1550 nm laser interferometer.
- The printer shall have a powder bed which moves up in order to deposit a new layer of powder.
- The printer shall have a roller to deposit powder from the powder bed to the print bed.

- The printer shall have a print bed which moves down after each layer is sintered by the laser.
- The printer shall have a collection bin which collects any excess powder that is not deposited on the print bed.
- Any component or device that deals with powder must be enclosed in a vacuum sealed container that is filled with a nitrogen/argon gas.
- All lasers shall be able to be adjusted to any point within the print bed using some sort of servo control system.
- There shall be a pressure and oxygen sensor inside the sealed powder chamber to check for safety hazards.
- There shall be an oxygen outside of the printer, to alarm the user if oxygen levels in the room are unsafe or low.
- The system shall use an interlock or locking system to prevent the laser to turn on unless the container's door is sealed.
- A camera will be added to provide eyesite in the sealed container and to visually see if there are any problems.
- Two temperature sensors will be used to measure the temperature of the inside of the sealed container as well as the temperature of the sealed containers' walls. This is for checking to make sure that the powder isn't getting too hot and to know if the sealed container is safe to tough.

4.2 Non-functional

- The vacuum chamber should use space efficiently.
- All code should be well documented and understandable to allow future users to edit easily.
- The printer should work as quickly as possible without affecting quality or causing safety issues.

4.3 Standards

Engineering standards assist with the creation of constraints for designing a technical product. Constraints allow for a group of engineers to critical think for a solution or goal for a project. Projects/devices are held to these standards to be easily transferable between platforms. The standards we will be following are the industry and IEEE standards.
All code generated will be written with supporting documentation in Javadocs style comments. This follows the software standards that are present in the industry standards. Meeting these requirements will allow easier understanding of the coding and how to modified the software.
Using a high power laser requires several safety standards to be followed. All of our team members will take the EHS Laser Safety training, and will work with EHS to ensure that the system and its environment is safe for testing.

The following are IEEE standards that pertain to our project:

270-2006 - IEEE Standard Definitions for Selected Quantities, Units, and Related Terms, with Special Attention to the International System of Units (SI).
This standard defines the physical quantities, units, and the systems of measurements that are used in applied science and technology. The standards emphasizes the use of the International System of Units. This is relevant to the team's project because half of our project is mechanically designed. We need to confirm that the parts of the printer are compatible with the design of the printer. Therefore, our team must be aware of the measurements/units for each part.

1100-2005 - IEEE Recommended Practice for Powering and Grounding Electronic Equipment.
This standard is a collection of best practices for powering and grounding electronic equipment used in commercial and industrial applications. The best practices are designed to enhance equipment performance and maintain safe installation. This is relevant to our project because we will essentially be building a device that needs proper powering and grounding. We will be using several lasers, implementing a sensor system, and powering a printer. We need to be able to properly distribute power and ground these systems for safe handling.

299-2006 - IEEE Standard Method for Measuring Effectiveness of Electromagnetic Shielding Enclosures.
This standard describes uniform measurement procedures and techniques to determine the efficiency of electromagnetic shield enclosures. This includes welded, demountable builds of materials such as steel plate, aluminum, and copper. This is relevant to the project because we will be using several lasers, including a high beam melt laser. We need to be able to have an enclosure that helps prevent any radiation and reflection to the user. This standard will help ensure that our device is safe to handle

754-2008 - IEEE Standard for Floating-Point Arithmetic
This standard specifies interchange and arithmetic formats and methods for binary and decimal floating-point arithmetic in computer programming environments. This standard is geared toward the software part of our project. Our printer will be controlled by a program that will control the movement of our printer by pushing coordinate values via arrays. We want to be able to store precise values as possible to maintain accuracy of the 3D printed product.

There are also some other standards by the International Organization for Standardization (ISO) for additive manufacturing that we will be following:

ISO/ASTM 52901:2017 - Additive manufacturing -- General principles -- Requirements for purchased AM parts
"Gives guidelines for the elements to be exchanged between the customer and the part provider at the time of the order, including the customer order information, part definition data, feedstock requirements, final part characteristics and properties, inspection requirements and part acceptance methods." (Naden 2018)

ISO 17296-2:2015 - Additive manufacturing -- General principles -- Part 2: Overview of process categories and feedstock

“Explains how different process categories make use of different types of materials to shape a product's geometry. It also describes which type of material is used in different process categories.” (Naden 2018)

ISO 17296-3:2014 - Additive manufacturing -- General principles -- Part 3: Main characteristics and corresponding test methods
“Specifies main quality characteristics of parts, specifies appropriate test procedures, and recommends the scope and content of test and supply agreements.” (Naden 2018)

ISO 17296-4:2014 - Additive manufacturing -- General principles -- Part 4: Overview of data processing.
“Specifies terms and definitions which enable information to be exchanged describing geometries or parts such that they can be additively manufactured. The data exchange method outlines file type, data enclosed formatting of such data and what this can be used for.”

ISO/ASTM 52900:2015 - Additive manufacturing -- General principles -- Terminology
“Establishes and defines terms used in additive manufacturing (AM) technology, which applies the additive shaping principle and thereby builds physical 3D geometries by successive addition of material.”

ISO/ASTM 52910:2018 - Additive manufacturing -- Design -- Requirements, guidelines and recommendations
“General guidance and identification of issues are supported, but specific design solutions and process-specific or material-specific data are not supported.”

ISO/ASTM 52921:2013 - Standard terminology for additive manufacturing -- Coordinate systems and test methodologies
“Terms included cover definitions for machines/systems and their coordinate systems plus the location and orientation of parts. It is intended, where possible, to be compliant with ISO 841 and to clarify the specific adaptation of those principles to additive manufacturing.”

5 Challenges

Some of the challenges we will have this semester will be working with a vacuum environment and making sure various components are able to function. Some examples of this will be a barometer, a thermometer, and most difficult likely being a camera that will not crack under high pressure. Another challenge will be getting software to interact properly with our roller used for depositing the metal powder on the bed and controlling various velmex motors to function in accordance with our predefined software and CAD files at a later date. These challenges will be difficult to solve but we should be able to overcome them and accomplish our goals as outlined in the below timeline.

6 Timeline

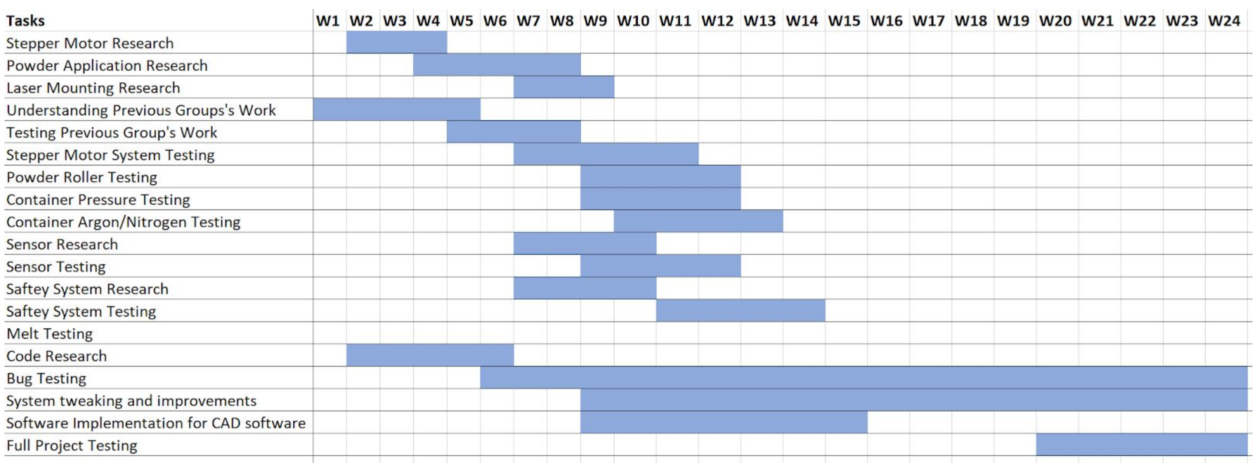

Figure 6.1 : Gantt Chart of Senior Design Fall and Spring Semesters

6.1 First Semester

The first semester will consist of research, design, purchasing of parts, understanding where the previous group left off and implementing the improvement we make on the individual aspects of the printer. In the beginning each member will research and understand the aspect of the project that they are most comfortable with. The software engineers will focus on expanding and improving on already created software, while the computer engineers will focus on the roller to work properly, and the electrical engineers will focus on adding in sensors for monitoring the device.

6.2 Second Semester

During the second semester, we will have a running prototype where the roller will be able to roll out powder and the laser will be able to melt it together. We will expand on the project if we such as creating software that will take CAD files and translating them to be able to be made by the 3D printer. The other engineers can continue tweaking the printer and adding more sensors. The 3D printer will be completed.

7 Conclusion

This semester and next semester we will be working on a 3D Metal printer that will hopefully be functioning by the end. The project was already started in previous semesters and although there is a good start on some of beginning design we still have quite a few challenges and decisions we will need to make in order to complete everything on time. Our current goals are to get the printer working as intended with the ability to create a cube by the end of the semester. We also hope to implement sensors to ensure that the environment for the printer is safe. These sensors will run through an Arduino and send an alarm to the user's computer if there is any issue. Our main challenges during this semester will be getting the program to interact correctly with a CAD file and to find a camera which is within our budget that will work under the high-pressure vacuum that we will create for the printer.

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