Next Generation 3D Printer

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Project Definition
Document

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Contents

1. Introduction

The engineering design program at Northern Arizona University (NAU) is striving to assist in the collaboration of its students with fellow organizations to help instill the necessary qualities and experience needed in future careers. As a realization of this ideal, the Novakinetics team has been organized through a senior-level capstone course to work with their client, Novakinetics, to conceptualize and design a more efficient and cost effective 3D printer which could be utilized in the production of aerospace composite molds and tooling.

With regards to manufacturing, the 3D printing process has many advantages as well disadvantages. Novakinetics recognizes both the advantages and disadvantages of 3D printing and sees a potential to use these printers due to their high accuracy and precision but are limited by production time and print size. Due to the limitations of most 3D printers such as print speed, print volume, cost, and accuracy on cheaper machines; the development of a new design is necessary. A design that can meet and surpass these disadvantages and limitations while maintaining product quality would greatly benefit companies such as Novakinetics. Such benefits include the reduction of labor, an increase in production speeds as well as decreased production cost. The following report will begin the process of designing a 3D printer. The first step in this process is to define the problem. In this section the needs statement, project goal, objectives, and constraints will be established. After that the Quality Function Deployment (QFD) will be created along with the corresponding House of Quality (HOQ) and project plan. Lastly, a benchmarking section will be discussed along with State of The Art Research (SOTA) pertaining to 3D printers.

2. Problem Definition

2.1 Needs Statement

Novakinetics is dissatisfied with the current lead time for creating molds and tooling and requires a different approach to creating their products.

2.2 Project Goal

The goal of the project is to aid Novakinetics in optimizing their manufacturing process by utilizing 3D printing.

2.3 Objectives

It is important to clearly outline the objectives by establishing a method of measurement for each objective as well as a corresponding unit of measurement. This allows us to quantitatively see how the final product meets each objective. The team's objectives are summarized in Table 2.1.

Table 2.1: Project Objectives

Objective	Measurement	Units
Fast Print Speed	Filament / Time	mm/s
Accuracy	Length	mm
Maintenance	Time	Hours/Week
Safe to Operate	OSHA	Unitless
Ease of Use	Time to Proficiency	Hours
Economic	Cost	US Dollars

2.4 Constraints

There are two different types of constraints for this project. The first type is the constraints of current 3D printing methods. These constraints exist given the nature of 3D printing. The second is the constraints of the client. Novakinetics has provided the team with the requirements needed to accomplish their need statement. In order to achieve these requirements, the team listed the constraints as shown in Table 2.2.

Table 2.2: Project Constraints

Constraints	Parameter
Part thickness	> 1.25mm
Surface dimension tolerance	±0.8mm
Resolution	< 0.5mm
Print volume	> 0.216m^3 (0.6m x 0.6m x 0.6m)
Power use	< 480V, 200A

Part thickness refers to the minimum length the part needs to be in order to print. This is a constraint that is very common on 3D printers. Surface dimension variance relates to the actual measurement of a print dimension in comparison to the desired dimension. Resolution is the fidelity of the printed part. The part will appear more smooth and defined as the resolution dimension decreases. Print volume is the volume based upon the dimensions in the x, y and z direction. More print volume means larger parts can be created. Finally, power usage is the total power the final design will use. Low power usage is desired in manufacturing because the company will spend less money running the machine.

3. Quality Function Deployment (QFD)

3.1 Introduction

The following section discusses three important techniques for the problem definition. The Quality Function Deployment (QFD) is the first step to be taken after meeting the client. It establishes a starting point and sets up the rest of the project. After the QFD is established the House of Quality can then be created in order to compare the engineering requirements formed from the QFD. Lastly, a project plan is formed in order to keep the team on track for the rest of the project. The following sections will discuss these three techniques in further detail and how they relate to this project.

3.2 QFD

After talking and meeting with Novakinetics, the team was able to ask important questions in regards to the project goals. The QFD located in Appendix A, Table 3.1, was created after the first meeting with Novakinetics. The questions asked form the basis of where the team's customer requirements come from. Some of the customer requirements are having a large print volume, the use of multiple print heads, faster time to produce the final product, and the ability for the printer to create complex parts. Keeping these customer requirements in mind, the team then came up with engineering requirements. These are important to keep in mind when trying to achieve all of the customer requirements. Some of the engineering requirements include size of both the machine and parts, time, heat, efficiency, extruder size, and vibrations.

After these engineering requirements were established, they were then compared to the customer requirements. This is done in order to determine the most important engineering requirements for the particular set of customer requirements. By reference of the QFD, the X's are denoting a relationship between the customer requirements and the engineering requirements. The important engineering requirements are the ones that have the most amount of X's. For this specific project, it can be noted that the most important engineering requirements are time, efficiency, and vibrations. These engineering requirements are going to be the main ones the team will focus on when designing the new 3D printer. Now that the engineering requirements are established, a house of quality can be formed.

3.3 House of Quality

The HOQ is essential in understanding how each of the engineering requirements are related to each other. The HOQ is a visual way of representing both the positive and negative relationships. The HOQ is located in Appendix B, Table 3.2. After reviewing the HOQ, it is important to note the positive relationships. An example of these include size and time. There is a positive relationship between the two because if the size of the parts being printed is scaled up, the time it takes to print it also goes up. An example of a negative relationship is between the extruder size and the time it takes to print a part. If the extruder is small, resolution will be better but this will greatly increase the time it takes to print a part. The house of quality is essential in determining these types of relationships. It will help the team in the design portion of this project by showing how different features in the design affect the final outcome. In order for the team to be successful and efficient a project plan was then created to keep the team on track.

3.4 Project Plan

The project plan found in Appendix C, Table 3.3, is what the team is planning on following in order to accomplish this project on time. The project plan is broken up into three distinct sections that correspond to the progress of the projects. The first is colored blue and represents the problem definition stage. The next section is purple and represents the design phase. With the help of both the QFD and HOQ, several designs will be proposed and with the help of a decision matrix one design will be chosen. This design will move into the final section of the project plan. This section is colored red and represents the prototyping and testing phase. The prototype will test the validity of the chosen design and will help to further refine the design to a final state. Important dates are located at the bottom of the project plan and will be used to remind the team of upcoming due dates. Now that the team knows what the client wants, the team will then conduct research in order to gain a better understanding of what is currently available on the market. The next section will discuss benchmarking and the relevant products that are already on the market.

4. Benchmarking

4.1 Introduction

To set benchmark performance expectations, it is important to research technology that is currently on the market. To begin the team's benchmarking process the team looked for 3D printers that utilize multiple extruders; however to the team's knowledge, there are currently no 3D printers that use multiple extruders on the market. Research was then focused on 3D printers with large print volumes of $0.216m^3$ or greater. This led the team to the BigRep One and the Fortus 900mc, two very different design approaches to a large scale 3D printer.

4.2 State of The Art Research (SOTA)

The BigRep One, as seen in Figure 4.1, is the first large scale 3D printer commercially available. It has a build volume of $1.1m^3$ (1.1m x 1.0m x 1.0m) with a resolution and positional accuracy of 100 microns. It is also one of the cheapest large scale 3D printers at around $30,000. However, the drawback to this printer is that the build volume has been increased tremendously, while the print speed is that of an average desktop 3D printer. The 3D printer that the team will design can solve this problem by using more than one extruder, but should also have a similar build volume and price point.

Figure 4.1: BigRep One [1]

Another 3D printer with a large print volume is the Fortus 900mc, as seen in Figure 4.2, made by Stratasys. However, this is an industrial 3D printer and far more expensive at around $200,000. It has a build volume of $0.486m^3$ with a resolution and positional accuracy of 178 microns and 90 microns, respectively. The advantage of the Fortus 900mc is the accuracy and reliability that come with such a high end 3D printer. The team hopes to achieve a similar level of accuracy and reliability with the team's final design, but at a fraction of the cost.

Figure 4.2: Fortus 900mc [4]

5. Conclusion

The client is Novakinetics, a company based in Flagstaff that specializes in composite aerospace parts. They are currently in need of a more efficient manufacturing process in order to reduce the lead time for molds and tooling. This can be achieved using 3D printing by optimizing the process for large scale printers while maintaining affordability. The objectives therefore are to increase the print speed, maximize accuracy, reduce maintenance, make it safe to operate and easy to use, as well as economic. The major constraint for this project is the print volume, which must be larger than $0.216m^3$. Through the QFD, the team discovered that time, efficiency, and vibrations will be the most crucial engineering requirements, so they will play a big role in the design process. Lastly, through SOTA, the team saw what is currently available on the market in terms of large scale 3D printers. With this knowledge, the team will draw upon the best attributes of various 3D printers on the market in order to meet all of the objectives and constraints.

6. References

[1] Bigrep.com, 'BigRep | Large Scale 3D Printing', 2015. [Online]. Available: http://bigrep.com/bigrepone/. [Accessed: 19- Sep- 2015].

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7. Appendices

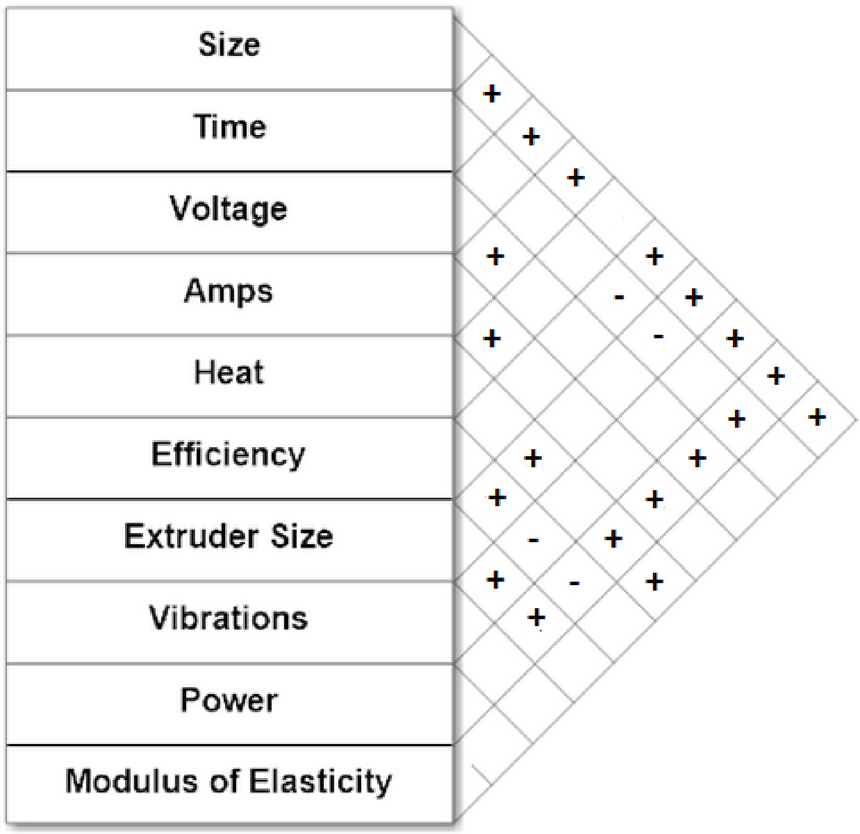
7.1 Appendix A: QFD

Table 3.1: QFD

		Engineering Requirements									
Customer Requirements		Size	Time	Voltage	Amps	Heat	Efficiency	Extruder Size	Vibrations	Power	Modulus of Elasticity
	Machine Footprint	X				X	X	X	X	X	
	Print Material		X	X	X	X	X	X		X	X
	Large Print Volume	X	X	X	X		X	X	X	X	
	Multiple Print Heads	X	X	X	X	X	X	X	X	X	
	Ease of Maintenance	X	X								
	User Friendly		X								
	Print Material Compatability		X			X			X		X
	Rigidity of Print Material					X	X		X		X
	Faster Time to Produce Final Product	X	X				X	X			X
	Ability to Create Complex Parts	X	X			X		X	X		X
	Layer Height		X					X	X		X
	Print Process	X	X			X	X		X		X
	Precision		X			X	X	X	X		
	Print Surface Finish		X			X	X	X	X		
	High Resolution		X				X	X	X		

7.2 Appendix B: House of Quality

Table 3.2: House of Quality



7.3 Appendix C: Project Plan

Table 3.3: Project Plan

	Task	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Week 9	Week 10	Week 11	Week 12	Week 13
1	Meet With Client													
2	Define Project Objectivess and Constraints													
3	Decision Matrix													
4	Quality Function Deployment													
5	Research Designs													
6	Research Coding Techniques													
7	Flow Chart For Coding													
8	Select Final Design													
9	Create CAD Models													
10	Create Code													
11	Select Materials/Components													
12	Estimate Cost													
13	Create Prototype													
14	Test Prototype													
15	Finalize Project Proposal													
	Project Definition and Project Plan Presentation		9/21/2015											
	Concept Generation and Final Decision Presentation								10/19/2015					
	Proof of Concept Demonstration												11/16/2015	
	Project Proposal													12/7/2015