ASME IAM3D DESIGN COMPETITION

TEAM 19
NEEDS ASSESSMENT
SUBMITTED TO ME DEPARTMENT

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SENIOR DESIGN FALL 2014
26 SEPTEMBER 2014

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1. Abstract

The needs assessment gives a better understanding of what the project is about and the goals that need to be met, and helps organize when assignments and deliverables are due. The Additive Manufacturing 3D Challenge (IAM3D) is hosting a challenge to re-engineer, or create from scratch a new 3D printer that minimizes energy consumption and improves energy efficiency. Team 19 will be designing a 3D printer that meets the goals of the competition and the goals of the sponsor. Most 3D printers print out plastic or ceramic materials by stacking layers on top of each other. However, Team 19's sponsor, Dr. Cheryl Xu, requests a printer that is capable of layering ceramics while being reinforced by Carbon Nanotubes (CNTs). Having a ceramic object that is reinforced with CNTs is beneficial because in enhances the material properties, such as the hardness and resistance to wear. Reinforcing the ceramic material with the CNTs is the main challenge because of how CNTs behave in a magnetic field at a certain temperature is hard to predict. The goals for the fall semester is to determine the cost benefit analysis, better understand the materials, understanding the competition rules, and experimenting with CNTs and designing the 3D printer suitable for these criteria.

2. Introduction

Over time, additive manufacturing has been developing by implementing new 3D printing techniques and introducing more materials to be printed. Some of its current uses include aircraft products, fashion products, automobile components, medical implants, and dental restorations. Demanding markets have driven the introduction of ceramics 3D printers, which represent an important advance for the manufacturing world, due to the complex properties of this polymer material. Currently, several ceramic 3D printing devices have been produced; however, in order to stand out from the others, important requirements should be fulfilled including an innovative design, full efficiency, high levels of creativity, and feasibility.

3. Project Definition

3.1 Justification and Background

3D printers have significantly advanced additive manufacturing processes for many diverse industries. Digitally designed products can now be replicated by laying down successive layers of material making up horizontal slices of the product design. This additive process eliminates waste by using only the necessary amount of material, allows unlimited personalization of products, and can reduce manufacturing time and costs when compared to conventional manufacturing methods.

ASME's IAM3D Challenge tasks undergraduates from around the world to "re-engineer existing products or create new designs that minimize energy consumption and/or improve energy efficiency". In regards to this, Team 19 will be designing a printer capable of layering ceramic material into the desired products with these ideals in mind. The biggest challenge presenting itself in this project will be the carbon nanotube reinforced polymer-derived ceramic composite forming the 3D objects – this material will require the team to delve into an area not yet refined in 3D printing.

Carbon nanotubes have incredible properties that open up a number of new applications for ceramics, while the ceramic composites offer the CNTs protection from mechanical stress, corrosion, and serve as a replacement for metals and plastics. Reinforced polymers are used in a number of technical applications and products including sensors, electronics, and fuel cells due to their ability to remain amorphous at extremely high temperatures and excellent bonding properties. An example of such a composite structure can be seen in Figure 1. A number of printer components must be specialized for the ceramic to ensure that it can be used.

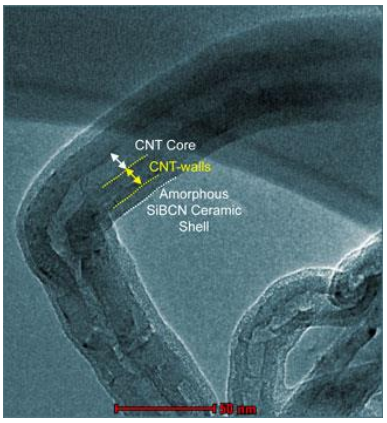


Figure 1 A Composite Structure of Ceramic Material and Carbon Nanotubes. Image Credit: Kansas State University

As for the sustainability and efficiency factor of the challenge, we have yet to determine the team's optimal approach. Ceramics have many advantages over metals; hardness values, resistance to wear, and the ability to withstand extremely high temperatures are all valuable properties in industry. These properties give ceramic based parts a longer service time than many metals and take less processing to obtain desirable results. With the introduction of the CNTs into their structures, the reinforced polymers offer a whole new spectrum of uses.

3.2 Needs Statement

The inaugural IAM3D Challenge is designed to give mechanical and multi-disciplinary undergraduate students around the world an opportunity to re-engineer existing products or create new designs that minimize energy consumption and/or improve energy efficiency. Students will showcase their creativity by demonstrating the value added through their ingenuity, application of sound engineering design principles, and leveraging Additive Manufacturing technology to address a broad spectrum of industrial, manufacturing, and humanitarian challenges.

A functional prototype of the top 30 designs, as chosen by a panel of judges, will be printed to the submitted design specifications and those students will be invited to present their designs and business case to panel of judges at the ASME 2014 International Mechanical Engineering Congress & Exposition (IMECE) in Montreal, Canada.

3.3 Goals Statement

The primary objective of the project is to have a functioning 3D printer that meets the competition guidelines by the end of spring semester 2014. The printer design will be experimenting with carbon nanotube reinforced ceramic composites. These objectives run in parallel, and deliverables designated for the project sponsor will not be affected by competition results. The main goals for fall semester are as follows:

- Perform rigorous cost benefit analyses at each stage of the design process
- Select engineering materials with an understanding on the unique properties and environmental impact
- Investigate the scientific and commercial applications of 3D printed polymer-based ceramics
- Use industry standard 3D CAD tools to assist the design and engineering process
- Submit a design that conforms to the IAM3D competition requirements
- Create a robust printer design that can be fully implemented in Spring 2015

3.4 Constraints

The obvious constraints of this competition are that the design has to be unique while following the code of ethics for engineers. This means that there is no reproducing or duplicating a design that is already on the market. The design should not harm anyone in anyway, and no laws should be violated. The only manufacturing constraint of the design project is that each team will be provided 150 cubic inch of construction materials in addition to support materials. Also, the manufacturing maximum build envelope is 3 ft. x 3ft. x 2ft. Constraints given by the sponsor includes a 2000-dollar budget. Also, the 3D printer should be able to print ceramic composites reinforced with carbon nanotubes.

3.5 Methodology

The team began the project by reviewing the design competition requirements to ensure that we will design or modify a printer to meet these requirements. The team is currently conducting background research on the unique properties of CNTs to gain a better understanding of the materials' advantages and limitations. This research will provide the team with knowledge on how to effectively incorporate CNTs into use as a new print medium. Additionally, the team will examine open source software for the Arduino microcontroller platform as a hardware to PC interface.

Next, key material properties will be determined for the various components of the printer. Once these properties are established potential material choices that are suitable for the design's operating parameters will be identified. A materials selection matrix will completed on these material candidates and focus on optimizing the design according to the constraints placed by the design competition.

Computer Aided Design (CAD) software will be used to model the printer design which will assist in the design and engineering process by enabling the team to make prompt changes to the design if issues arise. Furthermore, a cost benefit analysis will be completed on the design to evaluate the design on criteria including but not limited to cost impact and the amount of reduced materials. We aim to complete the design phase by the end of the academic semester.

3.6 Design Requirements

The ASME IAM3D challenge is open to all mechanical engineering students worldwide. Each team will need a faculty advisor from the university to approve of the design submission, and each team is only allowed to have one entry. A date for the registration has yet to be announced. However, in order to register the team needs to include a three-minute video about the team and a summary of their design. In addition each team will be required to submit the CAD files and a photo that describes their design concept, along with a written statement of the business case of the design. The registration window is typically six months long, so an ample amount of time is given to finish the design.

The business case should consist of several aspects. First, include the initial design ideas as well justification for any redesigning ideas. The business case should mention the budget that was given as well as the impact of the cost to the design. Also, briefly describe the sustainability and energy consumption of the 3D printer, and the materials used. The submission must not exceed five pages, and any images included must be in .jpg format.

Each design has to address a technical, economical, or environmental aspect of engineering. Each team is expected to follow the National Society of Professional Engineers (NSPE) code of ethics. Judging and scoring the design project is based on four different categories: the business case, innovation and creativity, efficiency and feasibility, and communication and presentation. The values of each category is listed in Table 1.

Table 1 Competition Scoring Criteria

IAM3D Judging Criteria	
Business Case	20%
Innovation and Creativity	30%
Efficiency and Feasibility	30%
Communication and Presentation	20%

3.7 Project Schedule

Great care will be taken by the team to ensure the timely submission of all deliverables; additionally, industry tools such as Microsoft Project, Dropbox, and Outlook Events will be employed to coordinate team meetings and communicate the status to project stakeholders. The current project schedule can be seen in the Gantt chart depicted in A1.

4. Conclusion

This multidisciplinary project is designing and building a 3D printer with certain criteria defined by the sponsor, design competition, code of ethics for engineers, and how CNTs behave. The niche behind this project is to have the polymer derived ceramic stronger by utilizing the CNTs and their properties and creating a reinforced ceramic base different from the rest of the designs. To do this we are contacting several faculty who have significant expertise in CNTs ceramics and 3D printing and talking with them about the properties of the materials. Later on based off of the information we have gathered, we will design the components of the 3D printer keeping in mind various aspects. Cost benefit analyses will be conducted to ensure that the end product will be commercially available. Better understanding the materials and the rules of the competition as well as an outstanding understanding of the sponsor/advisor/mentors is very important. Also understanding the alignment of CNTs, how they combine with the ceramic and incorporating these 3 areas on an additive manufacturing field is going to be challenging and exciting. The products will have many applications in different varieties as we construct the project get product out of the printer. This project and its members are going to work efficiently with a lot of productivity and creativity to solve the obstructions on the way while meeting the self-defined goals.

5. Works Cited

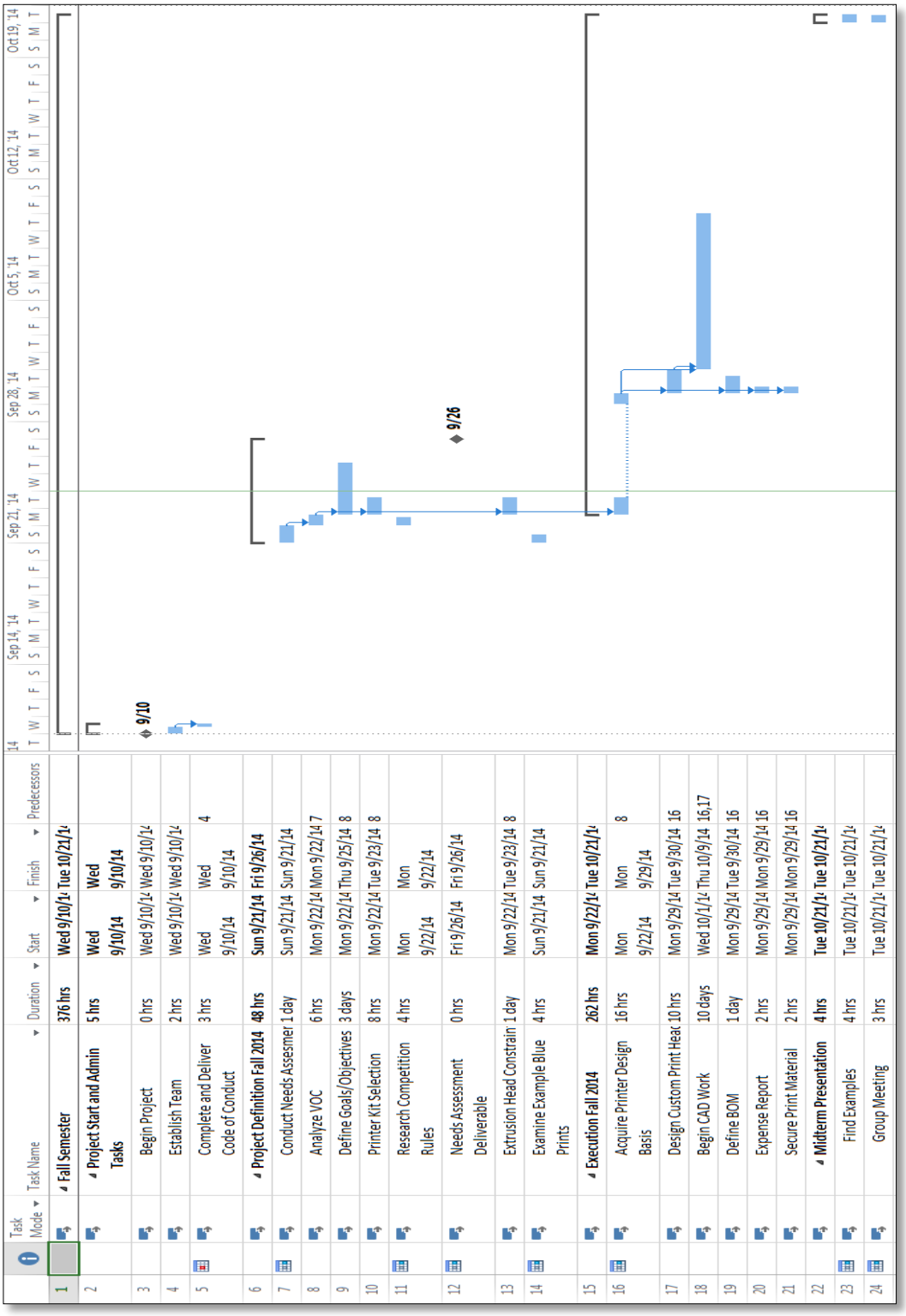
ASME. *IAM3D Challenge*. n.d. Web. 15 September 2014.

Kroll, Peter. "Modelling Polymer-Derived Ceramics." *Journal of the European Ceramic Society* 25 (2005): 163-174.

RocCera. *Advantages of Ceramics Vs. Steel*. n.d. Web. 15 September 2014.

6. Appendix

A1 Gantt Chart



	Task Mode	Task Name	Duration	Start	Finish	Predecessors
1		Fall Semester	376 hrs	Wed 9/10/14	Tue 10/21/14	
2		Project Start and Admin Tasks	5 hrs	Wed 9/10/14	Wed 9/10/14	
3		Begin Project	0 hrs	Wed 9/10/14	Wed 9/10/14	
4		Establish Team	2 hrs	Wed 9/10/14	Wed 9/10/14	
5		Complete and Deliver Code of Conduct	3 hrs	Wed 9/10/14	Wed 9/10/14	4
6		Project Definition Fall 2014	48 hrs	Sun 9/21/14	Fri 9/26/14	
7		Conduct Needs Assesmer	1 day	Sun 9/21/14	Sun 9/21/14	
8		Analyze VOC	6 hrs	Mon 9/22/14	Mon 9/22/14	7
9		Define Goals/Objectives	3 days	Mon 9/22/14	Thu 9/25/14	8
10		Printer Kit Selection	8 hrs	Mon 9/22/14	Tue 9/23/14	8
11		Research Competition Rules	4 hrs	Mon 9/22/14	Mon 9/22/14	
12		Needs Assessment Deliverable	0 hrs	Fri 9/26/14	Fri 9/26/14	
13		Extrusion Head Constrain	1 day	Mon 9/22/14	Tue 9/23/14	8
14		Examine Example Blue Prints	4 hrs	Sun 9/21/14	Sun 9/21/14	
15		Execution Fall 2014	262 hrs	Mon 9/22/14	Tue 10/21/14	
16		Acquire Printer Design Basis	16 hrs	Mon 9/22/14	Mon 9/29/14	8
17		Design Custom Print Heac	10 hrs	Mon 9/29/14	Tue 9/30/14	16
18		Begin CAD Work	10 days	Wed 10/1/14	Thu 10/9/14	16,17
19		Define BOM	1 day	Mon 9/29/14	Tue 9/30/14	16
20		Expense Report	2 hrs	Mon 9/29/14	Mon 9/29/14	16
21		Secure Print Material	2 hrs	Mon 9/29/14	Mon 9/29/14	16
22		Midterm Presentation	4 hrs	Tue 10/21/14	Tue 10/21/14	
23		Find Examples	4 hrs	Tue 10/21/14	Tue 10/21/14	
24		Group Meeting	3 hrs	Tue 10/21/14	Tue 10/21/14	