Ceramic Composite Printing

Team 19
Restated Project Definition
Scope/Project Plan

Team Members

Ernest Etienne - ME
Cody Evans - IE
Sonya Peterson - ME
Basak Simal - ME
Daphne Solis - IE
Sam Yang - ME

Advisors

Dr. Wei Guo, FSU
Dr. Yong Huang, UF

Project Sponsor

Dr. Cheryl Xu

Instructors

Dr. James Dobbs
Dr. Nikhil Gupta
Dr. Okenwa Okoli
Dr. Chiang Shih

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1. Abstract

Team 19 continues to make progress towards retrofitting the Taz 3D printer for Dr. Xu. The printer will extrude a novel material mixture consisting of a liquid polymer-based ceramic precursor and Carbon Nanotubes (CNT). This material slurry will be cured using ultraviolet light irradiation in order to produce solid part geometry according to supplied 3D model information. The end result of this printing process will be a reinforced ceramic matrix, with customizable material properties that can be made with arbitrary part geometry. In order to meet project goals, the team is performing material tests to define the behavior of the precursor and polymer slurry. Additionally, the team aims to fully integrate the custom hardware into the existing 3D printer motherboard. Previously, the project charter has included a provision to test the feasibility and design an apparatus to induce alignment of the CNTs in solution, this aspect of the project has been de-emphasized after consultation with project advisors and material experts.

2. Project Scope

The project scope is to develop a novel application of commercially available 3D printing technology. A liquid polymer precursor, will be mixed with Carbon Nanotubes (CNT) to form a chemical slurry, serving as the printing material of the repurposed 3D printer. This slurry will be cured after a single layer of printing with the use of ultraviolet spectrum LEDs. CNTs within the slurry will be aligned to some extent, using the methods of magnetic field alignment or electrophoresis. This product will be providing a prototype-level product that will act as progress towards strengthening the transformation method of the polymer from its liquid state to its solid state. The printer will be performing this transformation in the lab.

3. Background

Team 19's project is sponsored by Dr. Cheryl Xu. The sponsor has requested that at the end of the spring semester a 3D printer will be able to deposit a liquid slurry reinforced with CNTs, and that this slurry will be cured and the CNTs aligned once deposited on the print stage. The material that the printer will use to create solid parts is a liquid polymer precursor that after being cured by UV light solidifies into a translucent material with similar properties to epoxies and other thermosetting resins. After the material is cured, it can be subjected to pyrolysis whereby the polymer structure is converted to a ceramic material composed mainly of silicon carbide (SiC). It is to this precursor that the CNTs will be added, in order to achieve the performance desired by the customer. Adding CNTs to the polymer should significantly alter its mechanical properties such as strength, electrical conductivity, and thermal conductivity. Team 19 will be retrofitting a Fused Deposition Modeling (FDM) format 3D printer. Extensive modifications will be made to the printer: the FDM extrusion head will be replaced with a syringe pump, and the curing process will be accomplished by the aforementioned LEDs an array. These components will be controlled by the printer motherboard in tandem with a slaved Arduino microcontroller board.

4. Goals & Objectives for Spring 2015

The following is a list of milestones that must be accomplished by the end of this spring semester. These milestones were determined through careful examination of our sponsor's requests along with advice and information from team advisors and instructors.

- Complete testing of variables including distance of the needle from the printing platform, flow rate, and precursor viscosity
- Print a multi-layer solid part with the specified precursor
- Incorporate a polymer curing method into the printer
- Deliver proper organization and documentation of project expenses and components
- Set up a printer control system using a desktop PC to provide software control and video monitoring
- Draft an operations manual for the printer system to include a maintenance guide and schedule
- Provide guidance and training for sponsor-designated users

5. Project Update

5.1 Final Design

The Taz 3D printer will have its default extrusion nozzle removed and replaced with a syringe and needle controlled by a servo motor from a syringe pump. UV lighting will be implemented within the 3D printer space to cure the polymer as each layer is extruded onto the printer platform. All retrofitted components will be controlled with the Arduino Mega 2560 and RAMBO microcontrollers.

5.2 Challenges Faced

Working with the polymer has introduced a number of interesting and unplanned properties that must be accounted for in the extrusion and curing processes. Its viscosity is very much like water by itself, but with the addition of CNTs at just 1% mass, the viscosity becomes comparable to that of toothpaste. Numerous extrusion methods continue to be explored and experimented with to discover the optimal extrusion method for this material.

This project has required significant research and experimentation and has led to a number of discoveries, particularly the fact that it is unlikely that CNT alignment will be accomplished with the numerous methods that were once thought to be successful. After meeting with all of the advisors and some other professors with experience in this field, it was concluded that further research would be required before implementation of an alignment method could be included in this project, which would most likely be outside of the team's allotted time. Research into this aspect will be continued once all further components of the printer are completed. The parameters tested for will be frequency, field strength, light flux, and the percentage of CNT polymer in the matrix. The physical apparatus to test these parameters will be built, then the optimal numbers from all the parameters will be found through a series of tests.

5.3 Lessons Learned

A lot has been taken on by this team in the last two semesters and perhaps the biggest lesson learned is defining the project definition reasonably and realistically. Team 19's project definition evolved many times throughout the process and has led to many big changes in the structure of the team and tasks. This leads into perhaps the biggest lesson of all: a team and its members must be adaptable to the changes that will result from the discoveries made throughout the process, especially because these changes cannot be controlled. Expect the unexpected and be ready to adapt, otherwise any progress will be for nothing.

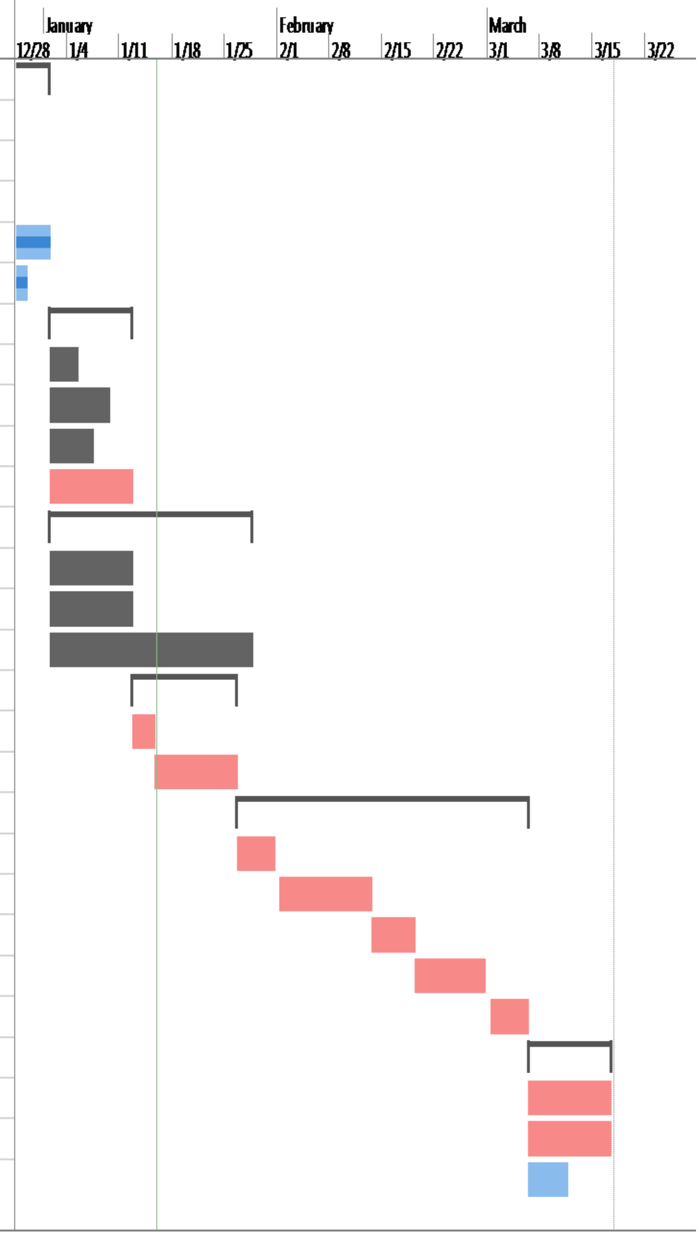
5.4 Procurement Update

A number of items have procured this semester, including

- Gooseneck clamp and video camera for monitoring the status of the print job;
- Laser infrared thermometer with laser for observing the heat gradient created during a print job;
- Both sharp and blunt-nosed needles for polymer extrusion testing; and
- UV LED lighting with an output of 20W to cure the polymer instantly

6. Gantt Chart

ID	Task Name	Duration	Start	Finish	Resource Initials	Predecessors
16	**1.5 Purchasing**	**8.55 wks**	**Mon 11/17/14**	**Thu 1/1/15**		
17	1.5.1 Arduino	2.1 wks	Mon 11/17/14	Thu 11/27/14	DS	3
18	1.5.2 Sensors	2 wks	Sun 12/14/14	Wed 12/24/14	DS	14
19	1.5.3 3D printer	2 wks	Wed 11/19/14	Sun 11/30/14	DS	10
20	1.5.4 Curing	6.5 wks	Thu 11/27/14	Thu 1/1/15	DS	11
21	1.5.5 Alignment	6.5 wks	Mon 11/24/14	Mon 12/29/14	DS	12
22	**1.6 Fabrication**	**2 wks**	**Thu 1/1/15**	**Mon 1/12/15**		**16**
23	1.6.1 LED Array	3 days	Thu 1/1/15	Mon 1/5/15		
24	1.6.2 Syringe Pump Mechanism	1.5 wks	Thu 1/1/15	Fri 1/9/15		
25	1.6.3 Inkshield Device	5 days	Thu 1/1/15	Wed 1/7/15		
26	1.6.4 Printed Components	2 wks	Thu 1/1/15	Mon 1/12/15		
27	**1.7 Testing**	**5 wks**	**Thu 1/1/15**	**Wed 1/28/15**		**16**
28	1.7.1 Droplet Size and Flow Rate	2 wks	Thu 1/1/15	Mon 1/12/15		
29	1.7.2 Curing Time	2 wks	Thu 1/1/15	Mon 1/12/15		
30	1.7.3 Alignment Assembly	5 wks	Thu 1/1/15	Wed 1/28/15		
31	**1.8 Assembly**	**2.6 wks**	**Mon 1/12/15**	**Mon 1/26/15**		**16,22**
32	1.8.1 PC and software setup	3 days	Mon 1/12/15	Thu 1/15/15	BS,DS,CE,EE	
33	1.8.2 Mount custom hardware	10 days	Thu 1/15/15	Mon 1/26/15	EE,BS,CE,SP	32
34	**1.9 Refinement**	**7.2 wks**	**Mon 1/26/15**	**Fri 3/6/15**		
35	1.9.1 Precursor only tests	5 days	Mon 1/26/15	Sat 1/31/15	BS,CE	33
36	1.9.2 CNT testing	12 days	Sun 2/1/15	Fri 2/13/15	EE,SP	35
37	1.9.3 Test analysis	1 wk	Fri 2/13/15	Thu 2/19/15	EE,SP	36
38	1.9.4 Improvement plan	9 days	Thu 2/19/15	Sat 2/28/15	CE	37
39	1.9.5 Rework	1 wk	Sun 3/1/15	Fri 3/6/15	EE,BS,CE,DS,SY,SP	38
40	**1.10 Project Closure**	**2 wks**	**Fri 3/6/15**	**Tue 3/17/15**		**34**
41	1.10.1 Create operation manual for	10 days	Fri 3/6/15	Tue 3/17/15	EE,BS,CE,DS,SY,SP	33
42	1.10.2 Draft handoff plan	10 days	Fri 3/6/15	Tue 3/17/15	BS,CE,DS,EE,SY,SP	37
43	1.10.3 Write safety data, Material Safety Data Sheets	5 days	Fri 3/6/15	Wed 3/11/15	BS,CE,DS,EE,SY,SP	39



Revisiting of the Code of Conduct 1/14/2015

Below are the members of Team 19 and their titles. Team dynamics are to remain the same where members agreed to work as a team while accepting constructive criticism. They will remain professional and request help from each other as they see fit throughout the project. Decision making will be conducted by the majority of the team members and what the sponsor agrees to as well as considering what the advisors suggests.

Materials Specialist – Ernest Etienne

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Team Leader & Lead IE- Cody Evans

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Multidisciplinary Liason – Sonya Peterson

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Lead ME – Basak Simal

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Financial Coordinator - Daphne Solis

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Lead Researcher – Sam Yang

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Advisor – Cheryl Xu

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