ChargeForge: gang charging system for newly developed physiological monitoring device

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Team: Allison Rausch (Team Leader)
Jake Maisel (Communicator)
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Kenan Sirlioglu (BWIG)
Luke Blaska (BPAG)

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Problem Statement

A new wearable device for physiological monitoring, specifically designed for occupational safety in environments like heat stress and confined spaces, is currently being developed. The design contains a hard-shelled carrying case which provides protection but lacks trays that can connect physiological sensing devices with charging cables. Thus, the team is tasked to design and fabricate a gang-charging system to help solve this problem effectively and efficiently. Overall, the design should be able to transport, charge, and recuperate 40-50 sensors. The charging system ideally should indicate charge and UV levels. The final design should balance cost, durability, and manufacturability.

Brief Status Update

The team has been working on brainstorming material and method ideas for the tray and charging system design. The criteria has been chosen for the design matrix and each member will continue researching and refining the reasoning behind design matrix decisions. The team will meet with the client to ask all questions regarding the design matrix and design ideas for feedback and a new perspective.

Summary of Weekly Team Member Design Accomplishments

- Team:
  - Set up a client meeting on September 30th
  - Used researched data and client requests to complete the design matrix
- Allison Rausch

- Drew up multiple preliminary designs for the design matrix
    - Wrote up a list of questions for the client
    - Started Progress Report 3
- Jake Maisel
    - Drew up three preliminary tray designs for the case
    - Connected with our client to set up the next meeting
    - Researched materials for the tray design
    - Worked on the design matrix
- Yeanne Hwang
    - Drew up preliminary design of charging system with its dimensions
    - Compared and summarized the stiffness and characteristics of plastic filament materials available for 3D printing
    - Write Progress Report 3
    - Attend BSAC meeting
- Kenan Sirlioglu
    - Submitted Progress Report 3 and Design Matrix
    - Researched about Gang Charging Systems in Harsh Environments (LabArchives)
    - Created a design of the Gang Charging System with dimensions and a key (LabArchives)
    - Researched about a contending (HDPE) material for the tray
- Luke Blaska
    - Researched different materials for Design Matrix, specifically ABS
    - Experimented with Pelican Case CAD file to explore design options
    - Attended BPAG meeting

Weekly/Ongoing Difficulties

The team continues to research to understand the charging system portion of the project as well as the regulations. The team will begin working on Matlab figures regarding the tray designs. The team may initially divide with half researching the tray and half researching the charging system.

Upcoming Team and Individual Goals

- Team:
    - Meet with Client
    - Finalize design ideas for the tray and charging system
    - Continue researching and updating the LabArchives team notebook
- Allison Rausch
    - Continue material research for durable yet relatively lightweight materials
    - Add more questions to the list for client meeting
    - Research ISS and other safety requirements
- Jake Maisel
    - Start researching the instrumentation that goes into designing a gang-charging device
    - Work on Preliminary Design Presentation

    - Draw up more designs for trays
    - Add questions to ask client
- Yeanna Hwang
    - Progress the research on materials, focusing on its UV resistance
    - Fill out more questions on the list for meeting
    - Research informations and requirements for UV sterilizer
- Kenan Sirlioglu
    - Focus on the design aspect of the tray for the gang charging system an add an entry to lab archives.
    - Add questions for client meeting
    - Work the Preliminary Design Presentation
- Luke Blaska
    - Acquire information from the client on charger information and if/what we will need to do with electronics/wiring
    - Draw up and brainstorm ideas with that knowledge
    - Begin researching possible wire diagrams/circuitry info that we may need

Project Timeline

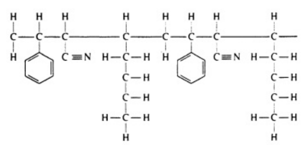
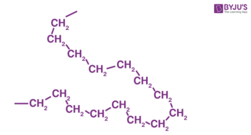
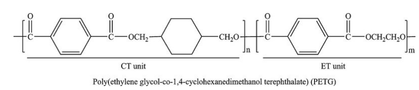
Project Goal	**Deadline**	**Team Assigned**	**Progress**	**Completed**
Product Design Specification (PDS)	September 19, 2024	All	100%	9/18/24
Design Matrix	September 26, 2023	All	100%	9/25/24
Preliminary Presentations	October 4, 2024	All	0%	
Preliminary Deliverables	October 9, 2024	All	0%	
Show and Tell	November 1, 2024	All	0%	

Poster Presentations	December 6, 2024	All	0%	
Final Deliverables	December 11, 2024	All	0%	

→ Arrows indicated dependencies

Charging Tray Material Design Matrix

Table 1: *The Design Matrix ranks the three designs based on durability, manufacturability, weight, safety, cost, and UV resistance with criteria weighted by importance. The final ranking shows that the ABS Filament won.*

Materials Design							
Material		ABS		HDPE		PETG	
Pictures		 *Figure 1: Chemical Composition of Acrylonitrile-Butadiene-Styrene [1]*		 Figure 2: *Chemical Composition of High-density Polyethylene [2]*		 Figure 3*: Chemical Composition of Polyethylene Terephthalate Glycol [3]*	
Criteria	**Weight**	**Score (max 5)**	**Weighted Score**	**Score (max 5)**	**Weighted Score**	**Score (max 5)**	**Weighted Score**
Durability	30	5	30	4	24	4	24
Manufacturability	20	5	20	4	16	5	20
Weight	20	4	16	5	20	3	12
Safety	15	3	9	3	9	5	15
Cost	10	4	8	5	10	4	8
UV Resistance	5	4	4	2	2	3	3
Sum	**100**	**Sum**	87	**Sum**	81	**Sum**	82

Criteria Descriptions:

Durability: The material must withstand handling and multiple trials without breaking apart. The material must withstand changes in temperature - between 241.48 K and 310.3 K. According to the PDS criteria, the client expects a lifespan of approximately 10 years.

Manufacturability: The design will be scored on the difficulty of manufacturing the tray and the charging system. This includes access to and effects of software necessity, machine accessibility, skill level requirements, and outside resource necessity.

Weight: The material should be lightweight enough to ensure the tray design is less than 6.8 kg.

Safety: The design will be scored on how likely the chosen material and charging system will produce any hazards during the construction process and during use afterward.

Cost: The cost of the design must fall within our budget of $300. The likelihood of excess material must be taken into account to reduce wasteful spending.

UV Resistance: The material must be able to withstand UV disinfection between uses. The effective dose for disinfection ranges from 5 to 10 mJ/cm^2 [4], but some systems can exceed 30 mJ/cm^2 for faster disinfection. The material should be fully functional after 100+ rounds of disinfection.

Ranking Analysis:

ABS:

Durability: Acrylonitrile butadiene styrene (ABS) is a sturdy thermoplastic with excellent durability. It has a Young's Modulus between 1.9 and 2.5 gigapascals (GPa) [5] and a tensile strength of 45 MPa [6], making it an excellent shock and vibration absorber while resisting cracking and fracturing under loading. These properties make it a popular choice in protective cases for electronics[5]. ABS has approximately 12.6 kJ/m^2 of impact resistance [7] and a melting point of 473.15 - 513.15 K [8], which fulfills our intended objective. As ABS exceeds the required durability goals, it scored a 5.

Manufacturability: ABS is commonly used in 3D printing and is available in the Makerspace. This allows for easy manufacturability as a design can be drawn on design software to exact measurements and specifications and then printed out. It can also be printed relatively quickly at 60 mm/s [9], which ensures there will be no warping or other imperfections during printing. As the Makerapace is easily accessible and 3D printing is relatively simple, ABS scored a 5 for manufacturability.

Weight: ABS is considered a lightweight material with a low density of 1050 kg/m^3 [6]. The density of ABS is slightly higher than HDPE and lower than PETG so it scored a 4.

Cost: ABS is a relatively inexpensive material, as it is comparable in pricing to the other materials at $15-20 per kilogram[10]. This price aligns with the project's budget, as the tray design will not exceed 1-2 kilograms. Thus, it scored a 4 for cost.

Safety: ABS is a non-toxic material and there have been no known adverse health effects reported due to long-term exposure[11]. One drawback of ABS is that it has low fire resistance and can be harmful when burned, but this would not ideally need to be considered for this project. As ABS has low fire resistance, it scored a 3 for safety.

UV Resistance: ABS exhibits moderate UV resistance with its thermal expansion of 90E-6 in/in*K [6] with a maximum working temperature of 343K [6]. Some special chemicals and coatings can be applied to enhance UV stabilization which helps to prevent color from fading and surface degradation[5]. Thus, it scored a 4.

HDPE:

Durability: HDPE is highly durable, with excellent impact resistance and the ability to withstand tough environmental conditions such as temperature fluctuations, humidity, and mechanical stress. The Young's modulus, which measures a material's stiffness and how easily it can deform or stretch for (HDPE) can range from 600 to 1500 MPa. [12] HDPE has a tensile strength of approximately 35 - 40 MPa [13]. This makes it ideal for military use where the device will be transported frequently and exposed to harsh environments. HDPE has a melting point of 390 - 410 K [13], well above our desired goal. With all these criteria in mind, HDPE scored a 4 on durability as it falls within our target temperature resistance and strength but could be more durable.

Manufacturability: HDPE is easy to mold because of its low melting point of 390 - 410 K [13] which makes it easy to manufacture in bulk through processes such as injection molding, extrusion, and thermoforming. For this reason, HDPE can be constructed in any shape that is needed for the gang charging system tray. The HDPE tray would be manufactured in the Engineering Centers Building which is easily accessible yet time consuming so it scores a 4 for manufacturability.

Weight: HDPE is very lightweight because of its linear molecular structure with few side branches, making it vital for a portable charging system. The density of HDPE is 930 to 970 kg/m^3. [14] As the lightest weight option, HDPE scored a 5.

Safety: HDPE is non-toxic, non-conductive, and chemically resistant, making it very safe for use in environments where it might be exposed to chemicals, moisture, or extreme conditions. However, HDPE is slightly flammable so it poses a risk if the charging mechanism overheats. With this possibility in mind HDPE scored a 3 for safety.

Cost: HDPE is cost-effective and similarly priced to other plastic filaments with HDPE, ABS, and PETG all costing around $15-$20/kg [10]. Its affordability, combined with its strength, makes HDPE a great option for large-scale manufacturing and for keeping the project within budget. Since there will be no additional 3D printing costs with HDPE, it scores a 5 for cost.

UV Resistance: HDPE does have some limitations when it comes to UV exposure. As a material, HDPE is not naturally UV resistant, meaning prolonged exposure to UV light, including UV-C light used for sterilization, can lead to degradation over time.A quantification of UV exposure for disinfecting the monitoring devices is 5 to 10 mJ/cm^2 [15] at 200-280 nm wavelength. Unmodified HDPE can degrade significantly after exposure to UV-C light for around 100–500 hours. Thus, HDPE scores a 2 on UV resistance.

PETG:

Durability: PETG has a high tensile strength of 31.3 Mpa and a Young's modulus of 2.01-2.11 GPa [16]. This allows PETG to sustain repeated impacts while keeping its overall shape and function. This is important because it will be subjected to harsh conditions that are found on military bases. The melting point of PETG is 538.5 K [17]. This is a very high melting point that makes the material ideal for sustained heat of the outdoors. Although PETG has a high melting point and a similar Youngs Modulus to the other options, it has a lower tensile strength than ABS so PETG scored a 4 for durability.

Manufacturability: PETG is a very easy material to manufacture because PETG is a 3D printable material. This allows the material to be shaped into any design concept for the charging tray. However, PETG prints at around 40-60 mm/s which can be slightly slower than the other materials.[18] As access to 3D printers is readily available, PETG scored a 5 on manufacturability.

Weight: This material is denser than some of the other materials that are being considered. PETG has a density of 1,260 - 1,280 kg/m^3 [19]. So it scored a 3.

Safety: PETG is a very safe and nontoxic material. This material does not pose a risk for the customer. The fumes that are emitted are nontoxic making it a safer material than ABS[]. Thus, PETG scores a 5 for safety.

Cost: PETG is cost-effective and has the same price as other plastic filaments with HDPE and ABS all costing around $15-$20/kg.[20] These are all very cost-effective materials. As a cost is associated with 3D printing, PETG scored a 4 on cost.

UV Resistance: PETG is a UV-resistant material, however, prolonged exposure to UV causes wear on the material. This degradation of the material can lead to a reduce mechanical properties by 30% [21]. This is very important because the tray will be exposed to UV. This could lead to rupture of the material due to photolysis. Thus, PETG scored a 3 for UV resistance.

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