e-Nable Prosthetic Grip Strength - BME 300/200

Product Design Specifications

September 24, 2021

Section 306

Client:	Ken Bice	ken.bice@gmail.com
Team:	Matthew Wroblewski	mdwroblewski@wisc.edu
	Kenzie Hurt	mhurt@wisc.edu
	Alexander Vazquez	arvazquez@wisc.edu
	Shreya Sreedhar	sreedhar3@wisc.edu
	Max Wieland	mwieland2@wisc.edu
	Sam Strachan	sstrachan@wisc.edu
	Jaime Barajas	jdbarajas@wisc.edu

Function: The client, Ken Bice, has requested that the function of the e-Nable *Phoenix Reborn* 3D printable prosthetic hand be altered to achieve an increased capability of cylindrical grip strength. Current models of prosthetic hands provided by e-Nable are very limited in their ability to grasp cylindrical objects smaller than a soda can, approximately 6.6 cm in diameter. The improved open cylindrical grip strength prototype should be able to hold a textured cylinder approximately one inch in diameter with significant mass for an extended period of time. Functionalities seen in the new product should remain largely the same if not improved when compared to the existing *Phoenix Reborn* model, minimizing substandard functionality sacrifices. Level of comfort should also be considered when developing the prototype to not have overexertion or harm to the user by straying too far from current standards. Simplicity and ease of use should also be considered so that users will not have to go through an overly intense learning curve prior to efficient and effective use.

Client requirements:

- Develop a prosthetic hand that is capable of an improved strength cylindrical grip
- Device must be able to pick up and hold a textured cylinder that will be supplied by the client
- Include a mechanism that limits overexertion of the user while using the prosthetic
- Ensure that the low-cost nature of the initial product is maintained with the prototype
- Possess equivalent or more accessible manufacturing intensity when compared to existing e-Nable models

Design requirements:

1. Physical and Operational Characteristics

a. *Performance requirements:* The prosthetic will be used daily by an individual of any age. Thus, the prosthetic must be able to withstand daily activities such as picking up and holding objects as well as general reinforcement and stability. The prosthetic is removable, but must be sized appropriately to the individual prior to use. The prosthetic will perform the cylindrical grip adequately.

b. *Safety:* Our design will be tested to ensure function without potentially dangerous failure at a given range. Any identified hazards will be reworked to prevent any injury wherever possible and proper use of the design will be conveyed to the user.

c. *Accuracy and Reliability:* The design will mimic the anatomy of a human hand with equivalent anthropometric sizes to that of the individual user. Elementary movements will be performed by the hand, with goal closure speeds of the fingers to be nearing that of functioning fingers, approximately 170-200 degrees/second [1]. The design will also be able to repeat these movements with minimal change in performance throughout its lifespan due to elastic deformation.

d. *Life in Service:* Per the client, 3D printed e-Nable prosthetic hands are currently designed to endure a lifespan of approximately two to three years of daily use with little maintenance or repairs. All changes to the design must meet or exceed this same life span.

e. *Shelf Life:* The final design will not use rubber bands as they break within days when exposed to high humidity areas, most frequently users who reside in tropical climates. The shelf life of the prototype will match the life in service of the current models, approximately two to three years. To account for the inability of rubber band use, elastic string is to be incorporated. Adolescent consumers are expected to upgrade to a different prosthetic size to accommodate growth after shelf life period and fully grown users can make repairs or reconstruction as necessary.

f. *Operating Environment:* The components of the prototype must withstand direct contact with surfaces of 37 ℃ (human body temperature), but also must withstand use in a variety of climates ranging in temperature from -25 ℃ to 40 ℃ and 40 - 80% humidity [2]. Proper function must also occur under mild daily accumulation of dirt and grime, but is expected to have a level of cleaning and maintenance given significant dirt build up.

The device must be able to operate without deterioration in aquatic conditions. The noise level should not increase beyond the current levels, which are not measured, but are not particularly jarring or disturbing in any given environment. Any modification to the design should not significantly interfere with the overall toughness or the peak/ultimate stress of the design from significant loading.

g. *Ergonomics:* The redesigned hand will not be designed for activities beyond that of standard activities of daily living. The product will act to be an improvement on the existing cylindrical grip to grasp objects like a door handle, soda can, or garden hose.

h. *Size:* The size of the hand should not be less than a print of 125% model size per the client, for ease of construction. The size of the model hand provided to the team is 140% upscaled. Scaling the *Reborn Hand* [3] parts at 124% would result in: palm width (widest) of 80 mm, wrist joint (outer radius) of 75 mm, and a wrist joint (inner radius) of 64 mm.

i. *Weight:* The design should not exceed a weight of 400 g [4] to ensure ease of use and limit muscular strain on the user. It should also be noted that this weight is especially important to adhere to since the prosthetic stresses muscular structure rather than skeletal and thus can be perceived as heavier than it really is by the user [4].

j. *Materials:* Metals should not be used as they are heavy and expensive. Plastic filaments are easier to print and allow for the prosthetic to be worn in conjunction with electromagnetic devices. All plastic components must be an affordable 3D printable filament that is also a recognized safe material when under consideration as a biomaterial. Per the client's request, any additional components must be easily accessible and affordable, such as being available at most hardware and craft stores.

k. *Aesthetics, Appearance, and Finish:* Changes made to the design of the Phoenix Reborn hand should match the current characteristics of the hand wherever possible and only change to improve grip strength/function. The texture of the hand should be smooth with an absence of any sharp edges. The color is negligible as this is up to the consumer to choose their printer filament and make aesthetic choices as they please.

2. Production Characteristics

a. *Quantity:* The client requires one 140% upscaled size final prototype as a proof of concept with full functionality. Other prototypes should be constructed at a smaller scale for initial concept testing and design but in as minimal quantity as possible in order to keep overall cost down.

b. *Target Product Cost:* Final product cost should remain between current standards of $30-$45 for e-Nable models. Price increases innately result from greater percent upscale of the print requiring more material and thus being more expensive for the user.

3. Miscellaneous

a. Standards and Specifications: Due to the "at home" nature of the prosthetic's design and construction, there are not many ASTM standards that directly apply to the product. However, the team still needs to be mindful of ASTM D4964, Standard Test Method for Tension and Elongation of Elastic Fabrics (Constant-Rate-of-Extension Type Tensile Testing Machine) [5].

b. *Customer:* The client prefers whichever style would be the most suitable to increase the grip strength. There is no preference as to if the product has to be in the form of an addition to the design or an implementation into the current design. The client also does not require that the prototype be passive or active in nature.

c. *User-related concerns*: The main concerns regarding patient use of this device is overexertion. Extended use of muscles in the arm and wrist can lead to fatigue and the inability to complete various tasks. The design must be comfortable for long term usage for the user.

d. *Competition:* There are currently four e-NABLE hand designs that are on the market so the prototype has competition within the realm of the client. There are also many other designs such as the *Pisa/IIT SoftHand* [6] which uses adaptive synergies and friction based transmission to perform daily activities, as well as the *DEKA* arm [7] which has six powered hand grips.

References

[1] R. F. F. Weir, “Design of artificial arms and hands for prosthetic applications,” in Standard Handbook of Biomedical Engineering Design, 1st ed. New York, NY, USA: McGraw-Hill, 2003, ch. 32, pp. 32.1–32.61.

[2]Pidwirny, M. (2006). *Climate Classification and Climatic Regions of the World*. *Fundamentals of Physical Geography, 2nd Edition*. [Online] Available FTP: http://www.physicalgeography.net/fundamentals/7v.html

[3] enablesierraleone Thingiverse.com, “Reborn hand by enablesierraleone,” *Thingiverse*. [Online]. Available: https://www.thingiverse.com/thing:2217431. [Accessed: 23-Sep-2021].

[4] P. Wattanasiri, P. Tangpornprasert and C. Virulsri, "Design of Multi-Grip Patterns Prosthetic Hand With Single Actuator," in *IEEE Transactions on Neural Systems and Rehabilitation Engineering*, vol. 26, no. 6, pp. 1188-1198, June 2018 [Online] doi: 10.1109/TNSRE.2018.2829152.

[5] *Standard Test Method for Tension and Elongation of Elastic Fabrics (Constant-Rate-of-Extension Type Tensile Testing Machine)*, ASTM D4964-96, 2020

[6] Catalano, M.G; Grioli, G; Farnioli, E; Serio, A; Piazza, C; Bicchi, A., “Adaptive synergies for the design and control of the Pisa/IIT SoftHand” in The International journal of robotics research, p.768-782, Vol.33, [online] 2014 [Online] doi: 10.1177/0278364913518998

[7] Resnik, L; Frantzy, A; Borgia, M, “The DEKA hand: A multifunction prosthetic terminal device - patterns of grip usage at home” in Prosthetics and Orthotics International, 42(4), 446-454, 2018 [Online] doi: https://doi-org.ezproxy.library.wisc.edu/10.1177/0309364617728117