Prosthetic Hand

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1 Introduction

Prostheses have advanced significantly in their functional capabilities and appearances over the past few years. The latest trends in fabrication are elevating prosthetic comfort, function and appearance for thousands of prosthesis users. But most of the higher-end prostheses are way to expensive for most people, and while more and more people are eligible for prosthesis.

With the latest technology of 3d printing and accessibility to a 3d printer, the production of prostheses has become a lot easier and cheaper. With the open source community of 3d printing, everyone with access to a 3d printer can make a prosthetic for themselves.

In this document, I will assess a variety of materials based on their suitablility for prostheses whilst maintaining a comfortable fit.

2 Materials

Material choice plays a major role in prostheses. Prostheses must be both strong and lightweight, they must be able to withstand the extensive use of the owner without obstructing there range of motion.
Below I will review a variety of materials for our prosthetic hand.

2.1 Plastic

PLA and ABS are 2 of the most common FDM (Fused deposition modeling) desktop printing materials. Both materials are thermoplastics, meaning they become pliable or moldable at a certain elevated temperature and solidifies upon cooling. Via the FDM process, both materials are melted and then extruded trough a nozzle to build up the layers that create a final part.

Table 1 below compares the main properties between PLA & ABS:

2.2 Silicone

Silicone is a dynamic material that moves with the body while simultaneously offering an enhanced grip on the residual limb and improved suspension of the prosthesis. Silicone is mostly used in realistic looking prosthetics and for mold making.

Table 2 below gives the main properties of silicone:

Properties[1]	**PLA**	**ABS**
Density	$1.3g/cm^3$	$1.0 - 1.4g/cm^3$
Elongation	6%	3.5-50%
Flexural Modulus	4GPa	2.1-7.6 GPa
Melting Point	160 °C	N/A (amorphous)
Biodegradable	Yes, under the correct conditions	No
Glass Transition Temperature	60 °C	105 °C

Table 1: Comparing PLA with ABS

[1] *Sourced from MakeItFrom [1]*

Properties[1]	**Silicone plastic**
Density	$1.9g/cm^3$
Elastic Modulus	9.0 GPa
Max. Temperature: Decomposition	480 °C
Biodegradable	No
Glass Transition Temperature	200 °C

Table 2: Properties silicone plastic

[1] *Sourced from MakeItFrom [1]*

2.3 Carbon Fiber

Carbon fiber reinforced plastic (CFRP), is an extremely strong and light fiber-reinforced plastic which contains carbon fibers. Carbon fiber is often used in prosthetics, sports equipment, aerospace and wherever the high strength-to-weight ratio and stiffness from carbon fiber are required. CFRPs are composite materials. In this case the composite consists of two parts: a matrix and a reinforcement. In this case the reinforcement is carbon fiber, which provides the strength. The matix is usually a polymer resin, such as epoxy, to bind the reinforcements together. This makes the material properties depend on those distinct elements.

2.4 Metal

Alloys containing titanium are known for their high strength, lightweight, and exceptional corrosion resistance. Despite being as strong as steel, titanium is about 40% lighter in weight. Titanium is also formidable in its resistance to corrosion by both water and chemical media.
Because titanium has a low modulus of elasticity that means titanium is not also very flexible, but returns to its original shape after bending.

Aluminium is a very light metal with a specific weight of $2.7g/cm^3$, about a third that of steel. Its strength can be adapted to the apllication required by modifying the composition of its alloys. Aluminium naturally generates a protective oxide coating and is highly corrosion resistant which can be further imporeved by different types of surface treatments. This is particularly usefull for applications where protection and conservation are required.

2.5 Morphological chart

	PLA	**ABS**	**Silicone**	**Carbon**	**Titanium[1]**	**Aluminium[1]**
Easy of use	★★★★★	★★★★☆	★★★☆☆	★★☆☆☆	★☆☆☆☆	★★☆☆☆
Strength	★★☆☆☆	★★★☆☆	★★★★☆	★★★★★	★★★★★	★★★★★
Weight[2]	★★★★★	★★★★★	★★★★★	★★★★★	★★★★★	★★★★★
Elastic Modulus	★★☆☆☆	★★★☆☆	★★★★★	★★★☆☆	★★★★★	★★★☆☆
Price	★★★★★	★★★★★	★★★★☆	★★☆☆☆	★☆☆☆☆	★★★☆☆
Usability[3]	★★★★★	★★★★☆	★★★☆☆	★☆☆☆☆	☆☆☆☆☆	★☆☆☆☆

Table 3: Materials Morphological Chart

These values in this Morphological Chart are based on eachother.
[1] The material properties of these materials can vary based on the alloys used.
[2] Weight is based on how lightweight the material is.
[3] Usability in this case is based on how usefull this material will be for our prototype.

2.6 Conclusion

A combination of PLA, ABS and Silicone would be the best choice material wise. This is because PLA and ABS are easy to use for rapid prototyping, in a relatively short time we can put together a functional prototype. When further developing this prototype to a product i suggest to look into replacing parts with stronger materials. When it comes to silicone, silicone is very suitable for the grip pads. These pads make it easier to pick up objects.

3 Comfort

Comfort is an important factor for prostheses. The prostheses must be an addition for the user, so that the user benefits of the prosthetic instead of being a chore. Ideally the user shouldn't notice that a prosthesis is present. This makes the user feel like a normal person and that the prosthesis is part of the body.
Below I will describe which factors play a role in the comfort of prostheses.

Weight The user must be able to wear the prosthesis for long periods of time in order to be usefull, this is why the prosthesis must be lightweight. Otherwise the user has to carry the have load of the prosthesis and is therefore not sufficient.

Range of motion The user must be able to have a relatively free range of motion, so that the user doesn't feel restricted.

Fit The prosthesis must be securly fit to the user without impending the bloodflow. The fit shouldn't be to loose either, otherwise it will slip around all the time.

Breathability Because the user is wearing the prosthesis for longer periods of time, the user's skin needs to be able to freely breathe.

3.1 Conclusion

These are my recommendations for improving the comfort of our prototype:

Weight See section Materials 2 for my recommendation about materials and weight. Another way to minimize weight is by using light weight electrical components.

Range of motion All moveable parts in the prototype should be able to move freely. These parts shouldn't restrict the movements that the user has without the prosthesis.

Fit Make the prototype fit the users arm by giving a almost perfect fit.

Breathability This is done by giving the part that fits the users arm some breathing holes, whilst not compromising structural integrity.

References

[1] MakeItFrom. Material properties database. Available at `https://www.makeitfrom.com/`, 2009.