Development of 3D Printed Symbrachydactyly Prosthetic Hand

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Abstract*: Symbrachydactyly is a genetical problem occurred to newborn where the newborn experienced underdeveloped or shorten fingers. This condition will limit their normal as even a simple task of holding an item or pushing a button. A device is needed to help them gain a better life. The aim of this project is to fabricate a customized prosthesis hand using 3D printing technology at minimum cost. The proposed prosthetic was not embedded with any electrical component. The patient can only use the wrist to control the prosthetic part which is the prosthetic fingers. The prosthetic hand was also being developed with the patient specific features, which the initial design stage was adapted from a person's hand geometry using a 3D scanner. Next the model of the prosthesis was analyzed computationally to predict the performance of the product. Different material properties are considered in the analysis to present Polylactic Acid (PLA) and Acrylonitrile Butadiene Styrene (ABS) materials. Then, the prosthesis was fabricated using the 3D printing. The results suggested that PLA material indicated better findings and further be fabricated.

***Keywords*: Finite Element Analysis, PLA, Prosthetic Hand, Symbrachydactyly, 3D Printing**

I. INTRODUCTION

Latin-American Collaborative Study of Congenital Malformations informs that 3 out of 10000 newborns are born with symbrachydactyly [1]. It shows condition of fingerless to the newborns in which will not be improved over time. Even if the newborns grew up, the fingers will not be developed [2]. Example of these conditions is shown in Fig. 1. Since these conditions are not life-threatening, not much research is done to help them. Even simple task of pushing a button could be very hard for them as they had no fingers to push on. Most of them in the past can enjoy their life without any treatment as they are able to adapt with the conditions [3]. Some solutions that are available for them are not much helping. One of them is surgery which is the toe-transfer surgery in which the toe of the leg will be transferred to the hand acting as finger. It will only provide minimal function as they toe are too short to act as finger. The other solution is to have electrical-powered prosthetic hand but this prosthetic requires large space to place the electrical component such as the circuit board and power supply unit. It will be inconvenient to the user as the prosthetic hand will be bulky and heavy to be use [4].

Fig. 1 Symbrachydactyly Condition of Shorten Finger [5]

The main solution to these kinds of problem is to develop the prosthetic hand with no electrical component needed. The design of prosthetic hand that the project will be based on is from E-Nable company which uses the wrist to control the flexing of finger. The prosthetic hand will be fabricated using 3D printer to allow for faster and cheaper fabrication process [6]. By using 3D printing technology also allow the prosthetic hand to be customizable up to customer need. The design could follow the geometry of the user's hand to allow for more comfort and ease of use. 3D printing can also be done at anywhere in the world as long as 3D printer are available. The type of 3D printer that will be used for this project is the Fused Deposition Modelling (FDM) type which uses filament to build the prosthetic hand from 3D model. It is the cheapest type of 3D printing and are easy to use by everyone with minimal training [7]. Before fabrication, stress analysis is done to the design to determine whether it could handle the load of normal usage [8]. Analysis could be done to understand the behavior of the design in real life situation using the finite-element analysis. [9] The objectives of this project are to design the prosthetic hand for the symbrachydactyly using

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Computer Aided Design (CAD) software and to analyze the design on the critical part based on different types of material used for 3D printing in which for this case is the Polylactic Acid (PLA) and Acrylonitrile Butadiene Styrene (ABS) using a Computer Aided Engineering (CAE) software. The final aim is to fabricate the prosthetic hand using 3D printer. This project would significantly improve the life of those with no finger on either one hand or both hand as they could have an easier life by using the prosthetic hand. It would also open 3D printing for more applications in medical fields [10].

II. METHODOLOGY

This project consists of three major steps which are the (A) the design process, (B) analysis process and (C) fabrication process.

A. Design Process

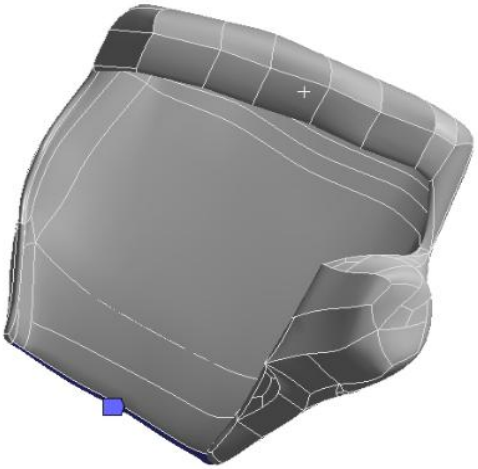
The first step in any design stages is to understand the problem in which that need solving. The problem that we are concentrating are on helping those people with symbrachydactyly problem to have a better functional life. Information regarding symbrachydactyly such as the current solution are gathered to help in establishing a new solution that would benefit these people. This project will develop a prosthetic hand based on a prosthetic hand from a company called E-Nable with some modifications and features added for a better comfort and functionality. Ideas and concepts will be generated and compared to pick the best for 3D designing. The design will be based on 3D scanned hand to provide best fitment for user and better control and comfort as per shown in Fig. 2.

(a) (b)

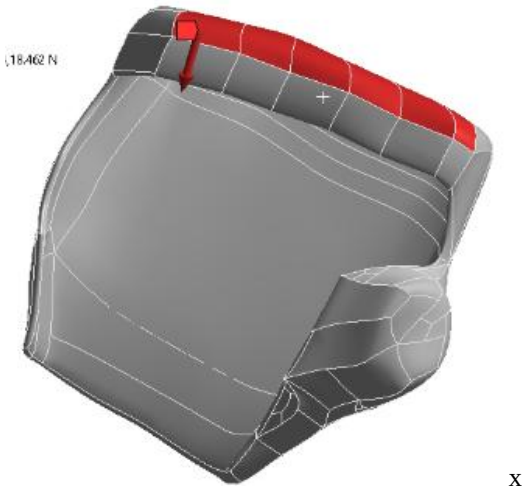
Fig. 2 Process of Making Prosthetic Hand from 3D Scanned Hand: 3D Model of the Symbrachydactyly hand (a), Finished design of prosthetic hand (b)

B. Analysis Process

For analysis part, only the most critical part will be analyzed using a CAE software. The part that will be analyzed is the palm cover as per shown in Fig. 2. The part will be tested on static analysis on different material used for 3D printing which is PLA and ABS. The placement of support and load of 10kg for the static analysis is shown in Fig. 3.



(a)



x

(b)

Fig. 3 Static Analysis Setting; Placement of Support - Purple Arrow (a), Placement of 10kg Load - Red Area(b)

The properties of the material used for analysis is shown in Table I. The setting used for this material properties on 3D printed part was of 100% infill and with the wall thickness of 1.2mm.

Table I Material Properties For 3D Printed Parts [5]

Material	Max Stress (MPa)	Stress Failure (MPa)
ABS	34.83	32.84
PLA	37.45	36.11

C. Fabrication Process

The design may need to be reworked if the result of the analysis does not meet or pass the requirement needed. Once pass, the design of all the prosthetic hand would be exported as stereolithography (STL) file to a slicing software called Ultimaker Cura for the software to generate a G-Code to be read by a 3D printer. Some settings are needed to be key-in such as wall thickness of 1.2mm and infill of 100%. The 3D printer will fabricate the prosthetic hand part by part. It will then be assembled to make a functional prosthetic hand.

III. RESULTS ANALYSIS

A. Design of Prosthetic Hand

For the design, the project had successfully designed a prosthetic hand based on a real 3D scanned hand model using a CAD software. The part that were customized according to the hand are the palm cover to give the best fitment for the patient. The concept that is used for this prosthetic hand is that at every connecting point of finger are connected with a rubber joint to allow flexing of fingers. Secondly, the prosthetic hand has connecting wires at each finger tips connected along the prosthetic hand until the wrist cover to allow control of the fingers by flexing of the wrist as shown in Fig. 4.

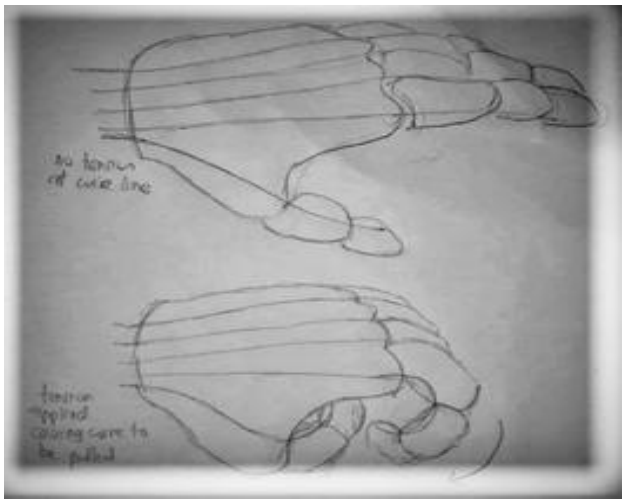


Fig. 4 Concept of Controlling Finger from Wrist Flexion: Relax Position (above), Gripping Position (below)

B. Finite Element Analysis

The analysis was done on the critical part which is on the palm cover using different materials which is PLA and ABS. The result of the analysis is that the stress and deformation as per shown in Fig. 5 and Fig. 6. Critical part of the design from the load applied is shown in Von-Mises stress view and also deformation view. The critical part or the highest stress occur is highlighted in red circle in Fig. 5. The highest deformation occur is also highlighted in red circle in Fig. 6.

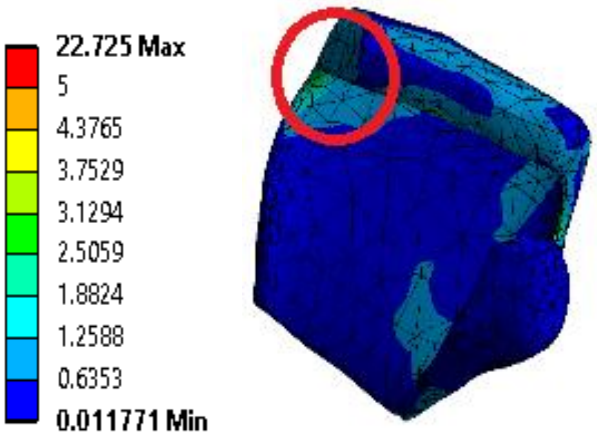


Fig. 5 Von-Mises Stress Result for PLA (MPa)

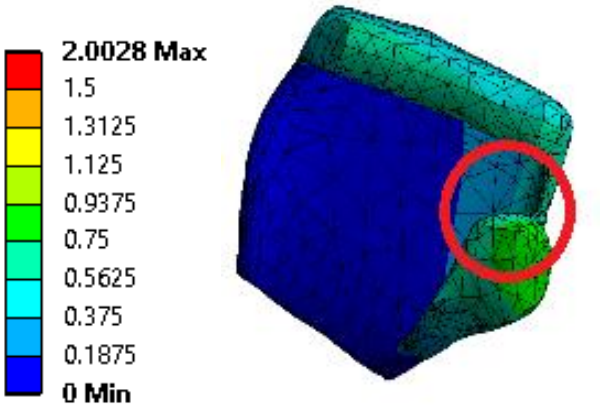


Fig. 6 Total Deformation Result for PLA (mm)

Stress occurred at both materials is about the same which is 5.141MPa for PLA and 5.073MPa for ABS but PLA could handle higher max stress compared to ABS which is 37.45MPa to 34.83MPa. The deformation occurred at both materials was too small which is below 1mm and was determined will have no effect on the design which is 0.8165mm for PLA and 0.9613 for ABS.

PLA has a small advantage in term of stress and deformation done. The huge advantage is that PLA does not emit toxic fumes during printing process which could endanger the operator as per ABS. PLA is also easier to be printed using the 3D printer compared to ABS which requires constant high surrounding temperature. From the analysis done, PLA had been chosen as the material that will be used for fabrication of 3D printed prosthetic hand.

C. Fabrication of Prosthetic Hand

Once analysis is done and the design had passed the required specification, the prosthetic hand design was exported as STL to a slicing software to generate a G-Code file for the 3D printer as per shown in Fig. 7.

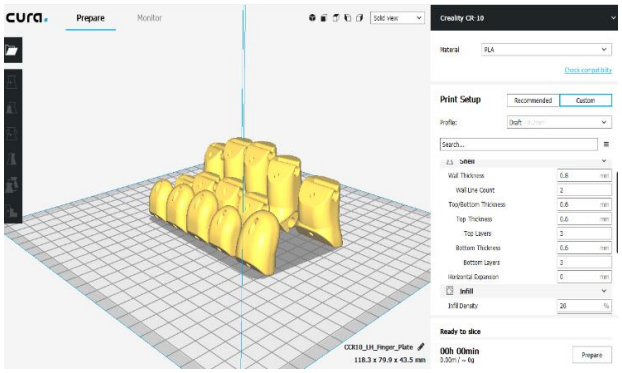


Fig. 7 Design Imported to Slicing Software

The material used for 3D printing is PLA as per determined in the previous section. The printer will print the prosthetic hand part by part before it was assembled to get a functional prosthetic hand as per in Fig. 8. The prosthetic hand was printed with the setting of 1.2mm thickness and 100% infill. Even the connecting joint which is the rubber joint is printed using the 3D printer, but the material used was Thermoplastic Polyurethane (TPU) due to its flexibility properties.

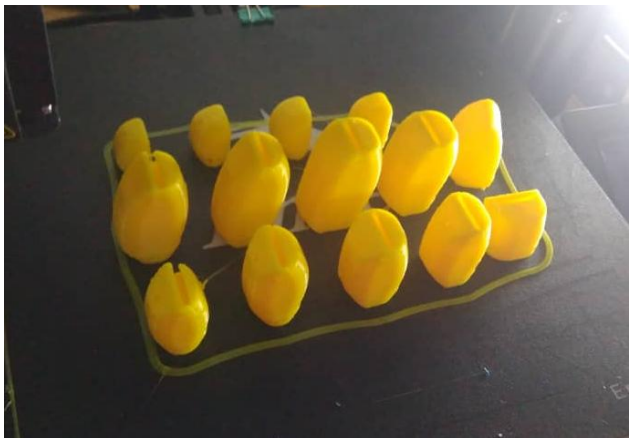


Fig. 8 Samples of the 3D Printed Part of the Prosthetic Hand

Once all the part finished printed using the 3D Printer, it could be then being assembled. The concept of the prosthetic hand is that it is connected by rubber joint to allow flexing of finger and connecting wires from every tips of the prosthetic finger connected all the way through the prosthetic until the wrist cover to allow control of the prosthetic finger. Completed prosthetic hand model is shown as per Fig. 9.

Fig. 9 Assembled Prosthetic Hand for Symbrachydactyly Patient

IV. CONCLUSION

The prosthetic hand was successfully designed, analysed and fabricated. Different material result in minimal differences from the finite element analysis with the PLA slightly better. PLA was selected as the material used for the fabrication of 3D prosthetic hand. The prosthetic hand was able to work as per concept which is using the wrist to control the gripping of the finger. The product could be improved if it was tested on real patient thus it is recommended to collaborate with any rehabilitation facility in the future.

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