The Design and Fabrication Practice of Compound 3D Printing with Hard and Elastic Filament - Assembley-free Prothesis Hand for Low-cost and Open source

Student ID:81449343
Name: Jianyou Li

1.1 Background:

This project is focus on the how to print a prosthesis hand with both flexible Nylon and rigid PLA material in a single FDM printing without subsequent assembly, and the flexible parts can take the hinge function as joint when driven by motors. In the Open Hand project of Yale university in our reference as fig 01, the prosthesis hand's tendons are made by hand-casted silicon parts, and requires two different types of prescription. The fabrication of prosthesis hand is very depend on casting skill, so this project was seeking the possibility to replace the silicon casting by the printing elastic material. If so, the complexity of whole fabrication process could be reduced by applying 3D printing only, and design freedom can overcome the limitation of casting technique.

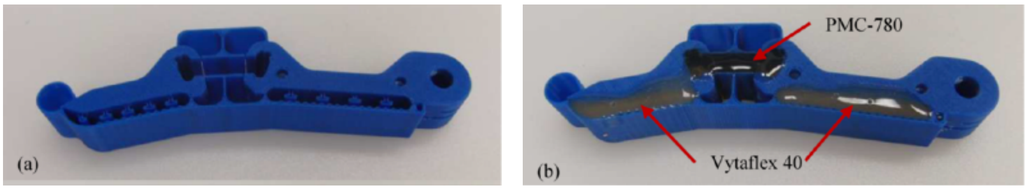

Fig 01. The casted elastic parts requires PMC-780 and Vytaulex 40 silicon in the open source of Open Hand by Yale University.

1.2 Material and hardware:

Considering the prosthesis hand product requires to contact the disabled people's remained limb, the material should be bio-capability and qualified to ISO 10993-5 and-10 certification. The Fabrial-R filament of JSR production as fig 02 and the rigid material, PLA are adopted in this experiment. The Fabrial-R has lower melt temperature about 145 degree and slower printing speed than printing PLA.

Besides, for printing both materials and changing setting parameters, a hackable 3D printer with duo-extruders is required. The MF-2200 3D printer of Mutoh Company and the Simply 3D are adopted as the main machine and G-code generator in the following experiment.

Fig 02. The Fabrial R filament of JSR

Fig 03. Mutoh MF 2200 3D printer

1.3 Limitation:

In our prior study, the product of silicon casting has much higher flexible performance than the printed object by the elastic Nylon material. The silicon part could be twisted, inflated, extended and bended, but the printed part needed to be printed in a Z-type folded structure as fig 04 to archive the limited twisting, extending and bending transformation. To archive the same bending angle for a tendon, the elastic Nylon requires longer length than the silicon one to equip enough Z folded structure.

Fig 04.The Z type folded structure

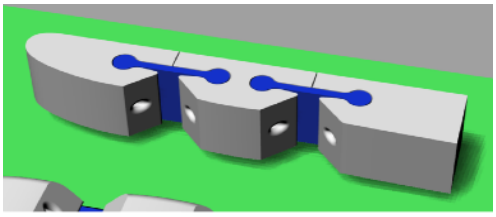

Fig 05. The prosthesis finger include two material

Besides, in the combinative printing test by a duo-extruders printer, two issues occurred in this test. The two materials, PLA and Fabrial-R require different stickiness and heating temperature on base bed. The PLA material requires the 60 degree for bed temperature, and Fabrial-R requires 45. The PLA can attach on paper tap, but Fabrial-R only attach on the special double-side tap, Nitton 5000NS50. In our test, if both materials will contact the heating bed as fig05, the bed should be placed with the double-side tap, and temperature could be set as 50 degree, but the PLA part has possibility can't attach on the bed very well.

2. Combining two properties into one material:

For solving the above problems in hybrid printing, we decided to focus on only printing Fabrial-R to simplify the preparation of bed environment. The solution is the not only applying Fabrial-R is as the elastic material, and also used to print the rigid part by increasing its thickness. Therefore, two special patterns that mixed solid part and flexible structure are developed as the Pattern A and Pattern B in fig 06.

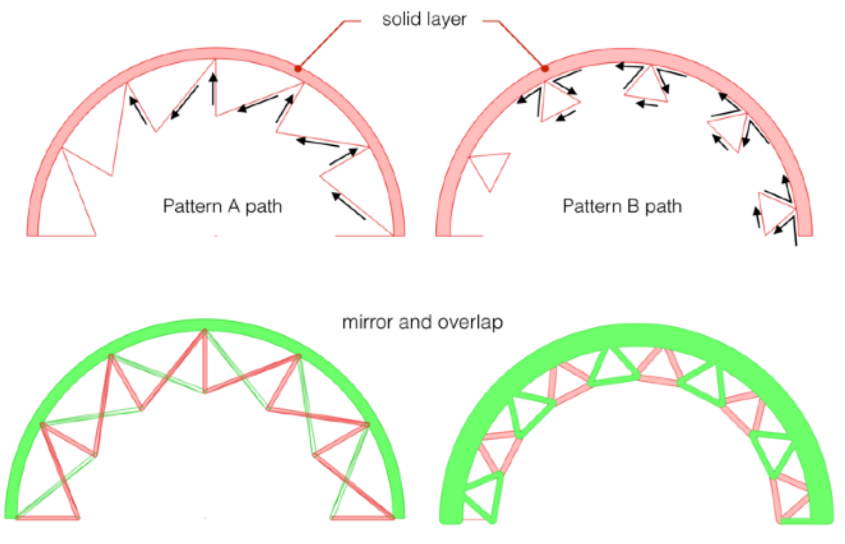

Fig 06. The process of how the structure repeat and overlap by mirror patterns.

These patterns are the prototypes to discover the possibility to enrich the multiple elastic performance in one single material, and the relationship between include a solid layer and a flexible structure. This placement could be controlled its flexibility by the thickness parameters of both layer. The structures are constructed by repeating the overlap mirror pattern as Fig06.

2.1 Printing test and evaluation

In the following test, the printings of two patterns's few layers are accomplished. The base layers are usually not completed, due to the melt filament sometimes can't attach on the heating bed well as the fig 07. Although the the higher layers have very high successful opportunity to be continued.

Fig 07. The test result of two patterns in few layers.

Comparing the rigidity of two patterns by directly hand pressing, the Pattern B has better flexible performance than A, but of course the parameters of structure distance and density can effect the performance. Therefore, we adjusted the two parameters to similar range and tried the second printing. Even in the similar solid thickness, structure distance and density, the Pattern A has more rigid touch than B, but consumed less time. Therefore we will focus on the Pattern B.

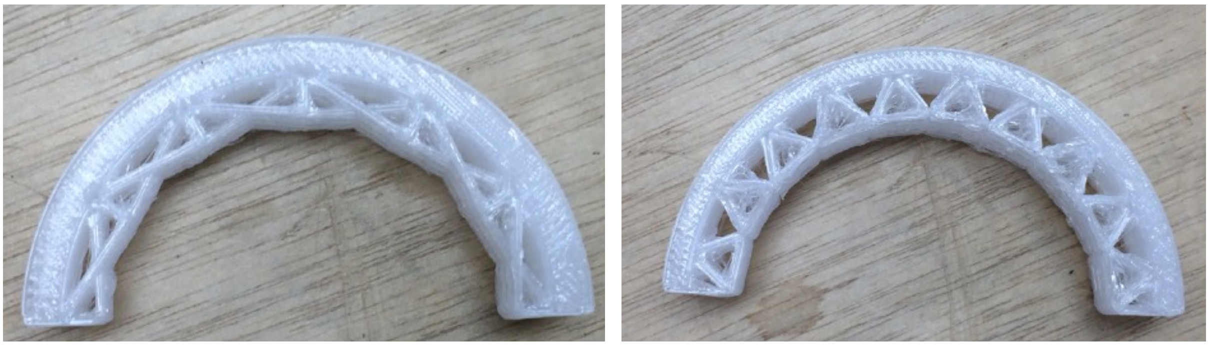

Fig 08. Second printing with adjusted parameters.

2.2 Advanced test

We tried a higher piece to test the printing stability in this stage as the Fig 09, and found that even some cell structure may failed to connect between points, but that doesn't effect other cells or cause further crushes. In the almost ten times of printing of this stage, the success rate is almost 95%, if under well base attachment.

Every layer's thickness in optimization should be 1.5 mm, if in 0.3 mm of printing layer, that means the printer has the chance to repeat every cell about 5 times, and that is enough to make up the cell, even the first two layers are failed. The pattern equips similar function as the support structure of 3D printing, but more strong connection to the solid layer.

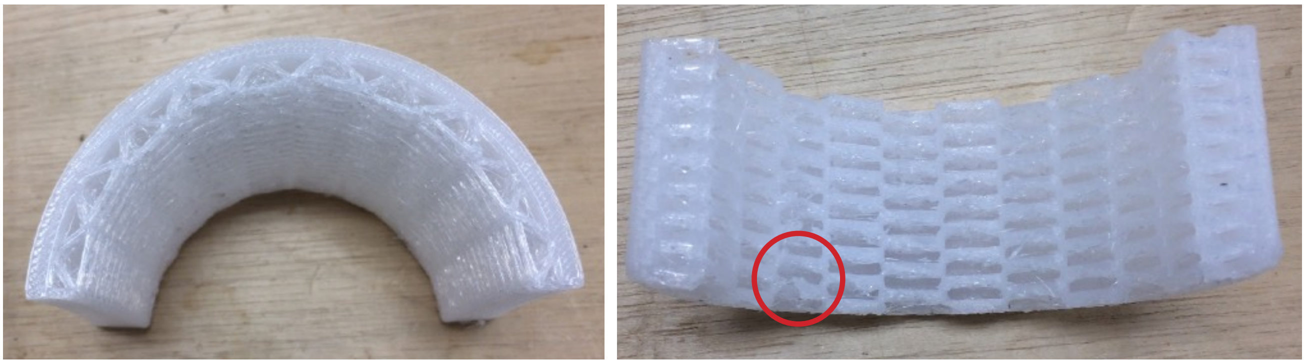

Fig 09. Printing stability test. The red circle points out the failed cell.

2.3 Application of prosthesis finger

In our past experience, the prosthesis finger is the most complex part in whole fabrication process, because one finger with 3 joints are consisted of by more parts than palm or wrist as the Fig 10. That also consume much time for the makers.

Fig 10. The fingers' design in other open source of prosthesis.

From our study result, the adjustable flexible pattern is applied on making the prosthesis finger in a single printing with Fabrial-R filament. This finger is not divided into 3 knuckles, but a bendable tentacle. The flexible structure can fix the bending direction, and keep the rigid in other directions. As some sorts of the prosthesis finger that triggered by the wires and linear servo, this finger can be bend by the same mechanism system. The main advantages of such finger design can simplify the fabrication and assembly process, and obtain the finger unit after the printing.

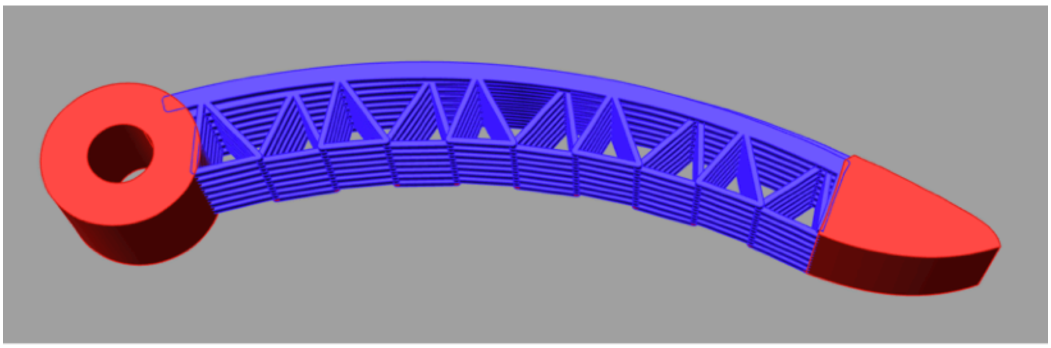

Fig 11. The bendable finger made by elastic filament and flexible structure.