Fabrication of Low Cost Prosthetic Arm with Foamed Fingers

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Abstract— *A lot of research is happening in medical field in the area of prosthesis with a aim to reduce the cost and at the same time, the artificial limb being effective. The current work concentrates on the area of prosthetic hand. Most of the prosthetic arms currently available are motor driven and costly. There are non-powered prosthetic hand also but involve the use of elastic band on solid fingers which make the arms heavy. The current work is aimed at overcoming these difficulties by the use of EPE foamed fingers which are driven actuated by a tendon by the gesture of palm while the foam provides the necessary spring back. CAD models are prepared using proe while 3D printing is used for fabricating most of the arm. EPE is used as foam material while PLA and Acrylic are used for outer structure.*

Keywords— 3D printing, EPE foamed finger, PLA, prosthetic hand, tendon driven.

I. INTRODUCTION

Human hand prosthetics is an increasingly interesting area in the field of medicine. With the advent of new materials and manufacturing technologies like 3D printing, a lot of advancements took place in this area. History as well as further prospects of 3D printing are given in [1]. Various materials used in 3D printing are detailed in [2]. The codes for 3D printing are achieved by mostly slicing stl files[3] and sometimes STEP files [4]. The application of 3D printing in product design has been briefed by 3DSystems[5]. Overview as to how 3D printing can be used for various applications is given in [6]. Fabricating using special materials like SMAs can also be achieved using 3D printing [7]. Even paper pulp can also be used for 3D printing [8] thus enabling low cost fabrications. An investigation into strength of FDM models using FEM is presented in [9]. The application of 3D printing in optics is discussed in [10].

The use of 3D printing medical industry has been discussed in various technical publications. Regulatory issues of the use of 3D printing in medical industry are presented in [11]. Protolabs [12] gave a detailed overview of various manufacturing processes that can be used in low volume medical industry. It also detailed the advantage of using additive manufacturing in this area. Researchers from HCL technologies [13] and TCS [14] explained how 3D printing can be used in health care industry. These applications include printing organs, cells, skin etc. 3D Printing of tissues and organs, generation of customized prosthetics, implants, and anatomical models etc along with advantages is detailed in [15]. Use of 3D printing for proper selection of surgical procedures for cardiac surgery [16]. A similar application where additive manufacturing is used for planning surgery and preparation of customized hip replacement is discussed in [17]. Mika Salmi [18] investigated into the way of combining Medical imaging and Additive manufacturing for customized dental applications. As a part of these investigations, CAD models are created based on CT scan images based on which implants are designed and 3D printed. The use of 3D printed PLA scaffolds for cell adhesion, proliferation and differentiation of human bone-marrow mesenchymal stem cells is discussed in [19].

The use of 3D printing for manufacturing low cost prosthetic foot is detailed in [20]. The current area of work is the human hand prosthesis. The guidelines for prosthetic arms are given in [21]. Tendon and motor driven prosthetic arm design is discussed in [22]. Prosthetic arms are also actuated by palm orientation and without using any external power source. The use of 3D printing for human hand prosthesis is given in [23]. Various types of human hand prosthesis that are currently existing are detailed in [24]. Zuniga, et al [25] designed a low cost 3D printed prosthetic arm for children with hand reduction because of various reasons. The use of low cost 3D printed prosthetic hand in daily activities along with the economic and environmental aspects is presented in [26]. James Burck, et al [27] used modal based system to design neural movement capable prosthetic arm.

II. PROBLEM DEFINITION

As mentioned in the earlier section, the aim of the current work is to design a low cost prosthetic arm for hand reduction using both CAD software and 3D printing. Most of the work that happened for designing prosthetic arms, involve the use of solid fingers in combination with elastic bands (which are responsible for spring back of fingers during opening of the grip).

The current work is aimed at replacing these fingers using foamed fingers. For these 3D printed fingers in which EPE foam is inserted are used.

III. MATERIALS AND METHODS

In the current work, Expanded Polyethylene (EPE) is used as foaming material. EPE is made from LDPE. It is a non-cross linked polymer and has good shock resistance and thermal resistance [28], [29]. The cushioning ability of this foam material helps in generating necessary spring back. Also since finger is being foamed, considerable reduction in weight of the finger is achieved. Fig 1 shows the image of EPE foam as an example.

PLA (Poly-Lactic Acid) is a biodegradable thermoplastic that is made from natural sources like corn seeds. PLA's properties like very low shrinkage during cooling, low warping make it ideal for 3D printing. Also 3D printed PLA has considerable strength and thus is chosen for making exoskeleton of the prosthetic hand designed. The exoskeleton is designed using pro/e. Fig 2 shows the prosthetic arm exoskeleton designed.

FIGURE 1: EPE FOAM USED

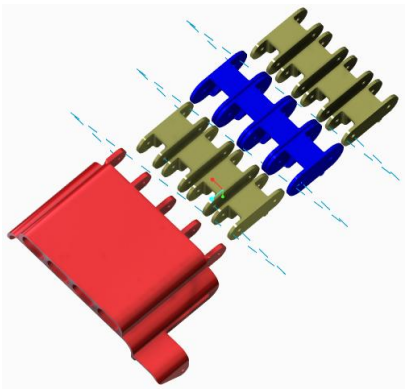


FIGURE2: DESIGNED PROSTHETIC ARM EXOSKELETON

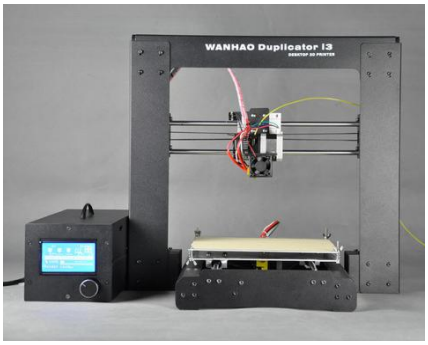
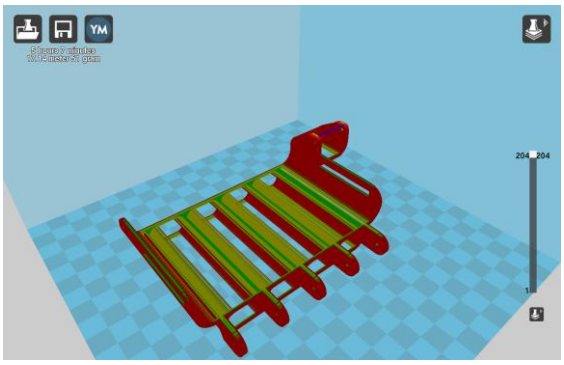


FIGURE 3: 3D PRINTER USED

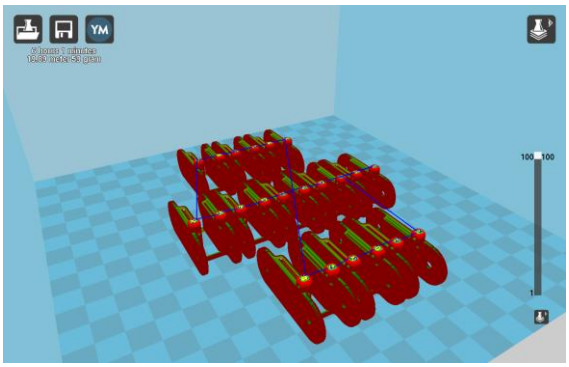
3D printing of the exoskeleton parts is carried out using Wanhao Duplicator i3 printer (Fig 3). The concept of 3D printing was first introduced by Chuck hull [30]. Various principles and methods now exist for 3D printing with most generally being slicing of stl files. In the current work, the modeled parts are exported into stl formats. Cura software is used for slicing the components.

IV. 3D PRINTING

Fig 4 (a) & (b) show the tool paths for extruder of the 3D printer to be followed for generating the designed component. Foam is inserted into the fingers manually by cutting from EPE sheet. The fabricated prosthetic hand is shown in figure 5. From the fig 5, it can be seen that foam is starting from the palm sleeve and continuing into the fingers. 3D printed finger exoskeleton provides hinged support to the palm cover/sleeve. Foam, during trials, proved that it can provide excellent spring back for fingers and thus enables opening of grip without the use of extra elastic material.



(A) TOOL PATH GENERATED FOR PALM COVER



(B) TOOL PATH GENERATED FOR FINGER EXOSKELETON

FIGURE 4: TOOL PATHS FOR VARIOUS COMPONENTS OF PROSTHETIC ARM

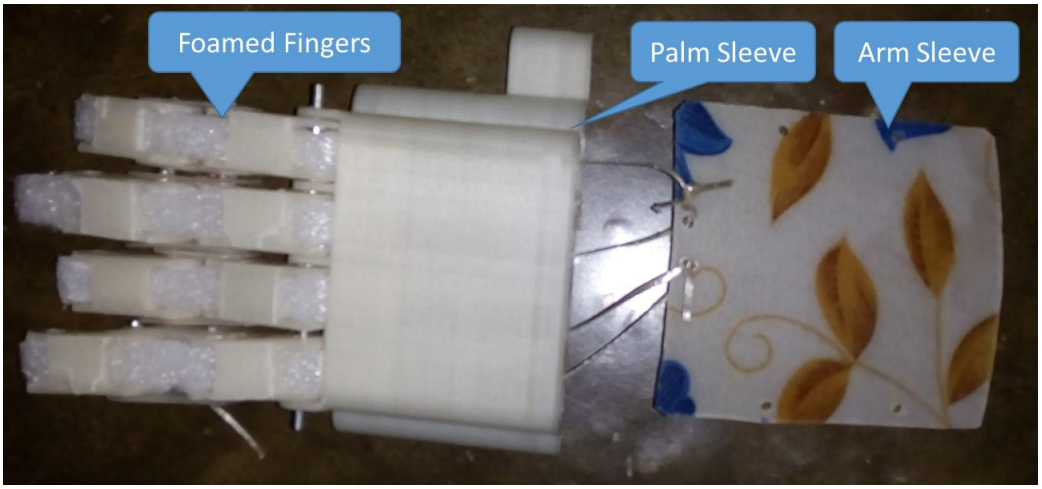


FIGURE 5: 3D PRINTED PROSTHETIC ARM

V. CONCLUSION

The availability of desktop 3D printers at low cost made it possible to fabricate customized prosthetic arms. The current work shows a new concept of prosthetic arm in which the regular solid 3D fingers are replaced with EPE foamed fingers. The exoskeleton of the fingers and the palm cover is 3D printed using PLA. Some parts like hand sleeve are made of thin acrylic so as to further reduce the cost by avoiding 3D printing where ever possible. EPE, by its material characteristics provides good spring back which helped in opening the grip automatically, thus avoiding the use of extra elastic bands.

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