DESIGN AND FABRICATION OF PICK AND PLACE MICRO-GRIPPERS

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ABSTRACT: This paper presents design and a simple fabrication process that allows isolated metal tracks to be easily defined on the surface of 3D printed micro-gripper components. The process makes use of a standard low cost fused deposition modelling system to quick deposit of thin film 'PLA' layers on to the surface of 3D printed polymer micro parts. As the end-effectors of micromanipulation systems, micro-grippers are crucial point of such systems for efficiency and reliability. This paper deals with design and fabrication of recently used micro-grippers. They are designed by uni-graphics software (NX 11.0) and fabricated by 3D printing. The designed and fabricated micro-grippers are offering stroke extending from 50 µm to 2mm(approximately) andwith maximum applied forces varying from 0.1mN to 600mN.These grippers are used to pick, hold and place macro/micro-components, which are widely used in the field of assembly.

Keywords: micro-gripper; microcomponents; micromanipulation; FDM printing; Additive Manufacturing; PLA Material;

1. INTRODUCTION:

The field of mechanical micro-machining deals with the production of miniature 3D components such as micro-shafts, micro-nuts, micro-spiral inductors, micro-motors etc; using a variety of engineering materials in the sub-millimetre (1-999 µm) range and bridges the gap between nano-scale and 'macro scale' manufacturing [1]. To handle these components, micro-grippers are required. The general requirement of a micro-gripper is that it should hold with sufficient force without breaking the component and release the components at a specified position. The positional uncertainty during assembly should be well defined and components should not get damaged. Microgrippers are used in the assembly of 'micro components' in various fields such as electronics, information technology, optics, medicine, biology areas like diagnostics, biological cells, biopsy tissue sampling, tissue engineering and minimally invasive surgery [2].

Grippers are classified based on the principles used such as mechanical, piezoelectric, thermal, electromagnetic, vacuum, etc; [2-5]. Different kinds of micro-grippers have been designed and fabricated since 1990. Among these mechanical microgrippers have high mechanical stability and can be used where electrical and thermal environments cannot be tolerated. The actuation is obtained by applying mechanical forces on a segment of micro-gripper. These forces are given by piezoelectric motor [6], micro drive control knob with tether cable drive [7], piezoelectric bar assembly [8] and micrometre turning with push and pull displacement causing tensile stress [9]. Hydraulic and pneumatic grippers are also used [10]. Michel Goldfarb and Nikola Celanovic developed a flexure based gripper [11]. Mechanically actuated silicon micro-gripper for handling micro and nano particles ranging from a few micrometres down to hundred nano metres. This gripper was designed to manipulate microstructures in the range of 5 µm to 50 µm. The design is based on push and pull displacement. It was actuated both mechanically and by using a piezoelectric stack. It was fabricated using traditional MEMS techniques and was able to open upto 130 µm. This is mainly due to the manufacturing process used by them cannot fabricate complicated three dimensional structures. The additive manufacturing techniques have been used in this work. Additive manufacturing is the process of fabricating objects from 3D model data by building materials layer by layer. This process allows highly complex geometries to be created directly from 3D CAD data without any tooling.

In this paper, polymer based mechanical microgrippers that can hold micro components are designed using uni-graphics software (NX 11.0). The fabrication is carried out using FDM printing process which is an additive manufacturing process. The designed and fabricated micro-grippers are offering stroke extending from 50 µm to approximately 2mm and with maximum applied forces varying from 0.1mN to 600mN.

2. DESIGN :

Micro grippers are designed using UNI-GRAPHICS (NX11.0) software. The grippers are made using PLA (Poly Lactic Acid) material. The PLA material micro-grippers are used in electrical power shocks to be observed in the pick and place microchips, pick the wirings etc. There are number of models to be designed for number of applications such as automobiles industries, medical fields, and electrical fields etc.

In micro biology to understand the behaviour and interactions between cells as well as to ensure about the heterogeneity of the cell population, it is necessary that the single cell displaced at specific locations, for this purpose we use micro-grippers. These grippers are used in the assembling of micro items like small gears, optical lens and micro-components of hybrid circuits. These are also used in medical field for eye, brain and nerve surgeries.

The design of microgrippers for holding circular 'micro components', micro assembly of industries and microchips of electrical fields and medical fields are pick and place the biological cells are carried out using UNI-GRAPHICS (NX11.0) software.

2.1. <u>Drafting</u>:

Firstly, the ***micro-grippers*** are drawn using the following commands:

1. ***Line:*** Creates lines with constraint inferencing.
2. ***Circle***: Creates a circle through three points or by specifying its centre and diameter.
3. ***Point***: Creates sketch points.
4. ***Arc:*** Creates an arc through three points or by specifying its centre and end points.
5. ***Profile:*** Creates a series of connected lines and/or arcs instring mode: that is, the last curve becomes the beginning of the next curve.
6. ***Studio Spline***: Dynamically creates and edits splines by dragging defining points or poles, and assigning slope or curvature constraints at defining points.
7. ***Offset curve***: Offsets a chain of curves that lie on the sketch plane.
8. ***Pattern curve:*** Patterns a chain of curves that lie on the sketch plane.
9. ***Fillet:*** Creates a fillet between two or three curves.
10. ***Chamfer***: Chamfer a sharp corner between two sketch lines.
11. ***Rapid Dimensions:*** Creates a dimensional constraint by inferring the dimension type based on selected objects and the cursor's location.
12. ***Geometric constrain***: Adds geometric constraints to sketch geometry. These specify and maintain conditions for or between the sketch geometry.
13. ***Mirror Curve***: Creates mirror pattern of a chain of curves that lie on the sketch plane.
14. ***Quick Trim***: Trimsa curve to the closest intersection or to a selected boundary in the either direction.
15. ***Quick Extend*** : Extends a curve to another nearby curve or to a selected boundary

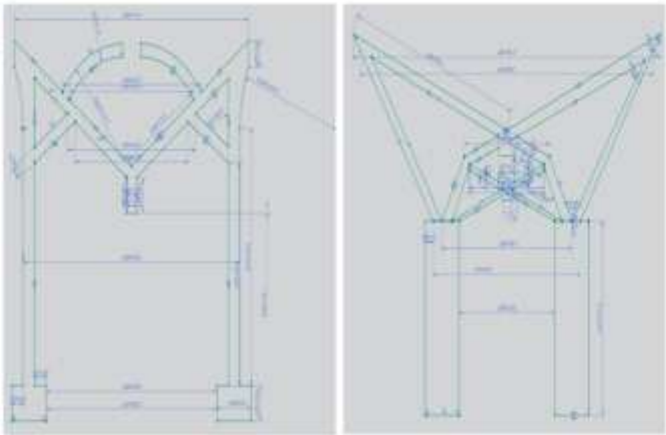


Fig 1. (a) *Side compression grippers*

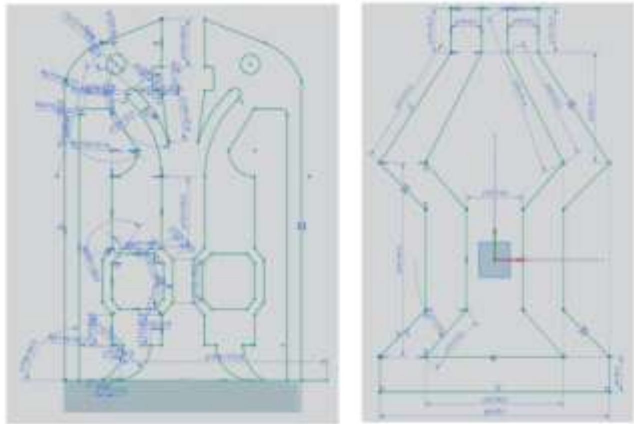


Fig 1. (b) *D*own ward forced grippers

The Fig 1. (a)' shows side compression force technique grippers. This type of grippers are used in the hold and place the nano and micro objects which can be easily picked.

The Fig 1.(b) shows down ward force technique grippers. This type of grippers are used in the pick and hold the micro and glass objects.

2.2 3D *Modelling*

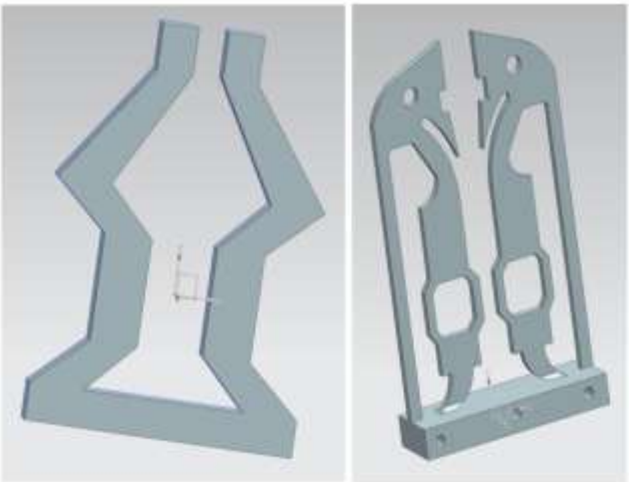
Drawn micro-grippers in 2D are converted into 3D objects by using the following 3D modelling commands:

1. ***Extrude***: Designs feature Drop-down.
2. ***Unite***: Combines the volume of two or more solid bodies into a single body.
3. ***Pattern feature***: Copies features into many patterns or layouts (linear, circular, polygon, etc) with various options for pattern boundary, instance orientation, clocking, and variance.
4. ***Edge Blend***: Rounds sharp edges between faces. The radius can be constant or variable.
5. ***Tube :***Creates a solid body by sweeping a circular cross-section along a curve with options for outer and inner diame

6. ***Swept volume***: Sweeps a solid tool body along path using various options to control the orientation of the tool with respect to the path and either subtracts it from or intersects it with a target body.

7. ***Mirror feature***: Copies a features and mirrors it across a plane.

Fig 2.(a) 3D mod



Else of Side force compression grippers

The above Fig 2. (a) shows the 3D model of Side compression force technique grippers. This type of grippers can be used in the hold and place the nano and micro objects are easily picked. This type of grippers can be used in electric circuits and holds the IC (Integrated chips), pick and support the wiring of electrical works

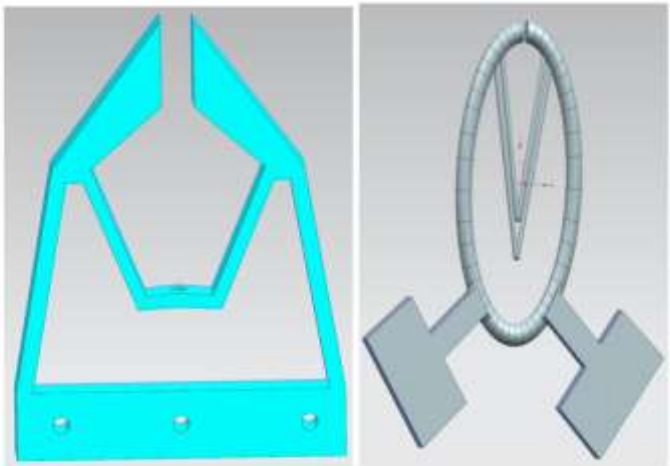
The above Fig 2.(b)

Shows the 3D model of Side and Down ward forced technique grippers. This type of grippers are used in the pick and hold the micro and glass objects. This type of grippers can be used in industries for holding work pieces for cutting operations.

8. ***Move face***: Moves a set of faces and adjusts adjacent faces to accommodate

Fig 2.(b) 3D models of Side and Down ward forced grippers

Fig 2.(c) Downward force grippers



In the above Fig 2.(c) Downward force technique grippers are shown. This type of grippers can be used in medical fields i.e., they can be used for stitches.

3. FABRICATION:

The micro-grippers are fabricated by using additive manufacturing in Fused deposition modelling process. In this process PLA material is used. The design of micro-grippers have to be into stl file (stereolithography file). The stl file will copy the object into the 'sd card' which is connected to the FDM machine. The 3D objects are changed in the position, direction and sizing by using 'Ultimakercura **3.1.0 '**software .The 3D objects are then converted into the 'G–codes and M-codes '. The G-codes are used to control the nozzle position and directions step by step. The generally used materials are PLA, PET-G, ABS, nylon etc. In this work we considered PLA for fabrication of grippers due to the following advantages.

3.1 PLA:

- PLA is poly lactic acid, a bio-degradable from of plastic that is manufactured from plants such as corn starch or sugar cane.
- PLA is much more environmental friendly since it is a bioplastic and not derived from oil. It can be completely recycled.
- The printed object is slightly smoother in appearance when PLA is used. PLA can be printed on a cold surface without deforming, so a printer does not need a heated bed.
- No harmful fumes are released when printing with PLA.

Properties:

S.NO	PROPERTIES	PLA MATERIAL
1	Density	1250 kg /m^3
2	Tensile ultimate strength	55 MPA
3	Tensile yield strength	53 MPA
4	Modulus of rigidity	3500 MPA
5	Poisson's ratio	0.39
6	Bulk modulus	5.2 MPA
7	Thermal conductivity	0.144 J/KG*C

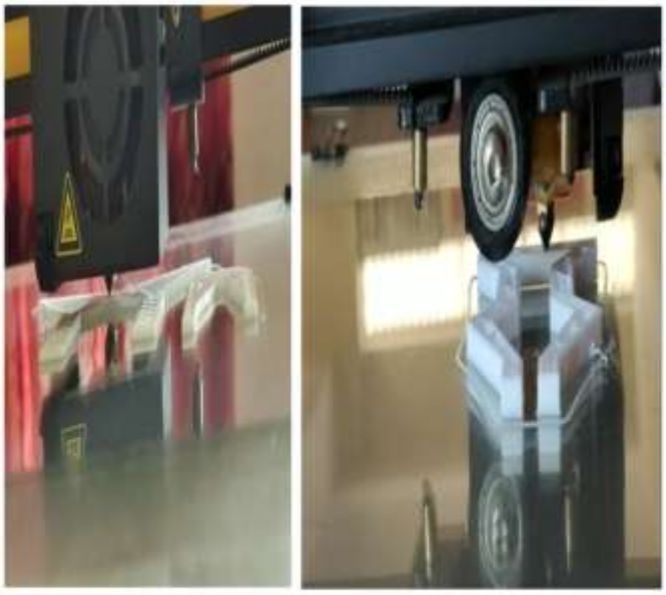


Fig 3. Fabrication process of micro-grippers

3.2 Fabrication process step by step:

- A spool of thermoplastic filament is first loaded into the printer. Once the nozzle has reached the desired temperature, the filament is fed to the extrusion head and in the nozzle where it melts.

- The extrusion head is attached to a 3-axis system that allows it to move in the X, Y and Z directions. The melted material is extruded in thin strands and is deposited layer-by-layer in predetermined locations, where it cools and solidifies. Sometimes the cooling of the material is accelerated through the use of cooling fans attached on the extrusion head.

- To fill an area, multiple passes are required. When a layer is finished, the build platform moves down (or in other machine setups, the extrusion head moves up) and a new layer is deposited. This process is repeated until the part is complete.

- Remove the supports of the printing object to get a clean surface of the object.

- Similarly one by one micro-grippers are fabricated.

4. RESULTS:

The micro-grippers are designed and fabricated in 3D printing process. The micro-grippers drafting is shown in Fig .1 and micro-grippers are modelled by using uni-graphics software as shown in Fig .2. The grippers are fabricated by using additive manufacturing FDM process as shown in Fig.3. Finally the 3D printing micro-grippers are designed and fabricated as shown in Fig.4.

Fig .4 3D printed micro-grippers.

5. CONCLUSION:

In this work, the microgrippers are designed and fabricated using NX 11.0 and Fusion Deposition modelling .They are offering stroke extending from 50 µm to 2mm (approximately) and with maximum applied forces varying from 0.1mN to 600mN and found wide applications in assembling of objects in various fields.

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