MECHATRONICS REPORT – 3.1.1

SONIT NITIN PATIL

bm23btech11023

Submitted For

—

Coordinator Selection

—

TINKERERS' LAB IITH (2024-25)

ROBOTIC GRIPPER: PREFACE

The presented Robotic Gripper is a product of ROBOTIQ, headquartered in Canada. It is a highly complex 3 finger adaptive robotic gripper capable of controlling each finger individually. It also has a tactile sensor to completely automate and pick up almost* any object of any size. This can be controlled using their own in-house software URcap.

It costs approximately $20000 (19 Lakh Rupees) which is a huge amount for 1 Robotic gripper. Also, the mechanism involves 3 servo motors and tactile sensors which allows it autonomous individual control of each finger with 4 different movement modes.
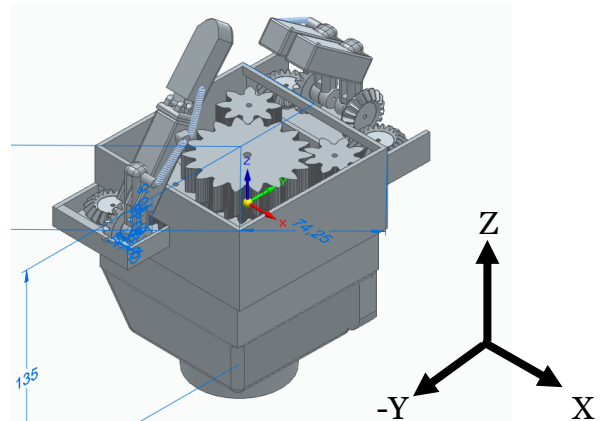
TASK – To optimize the complexity to simple mechanism which has sufficient dexterity and adaptability while keeping the cost low.

P

The Assembly

The figure alongside shows the final CAD image of the SolidEdge assembly of the Mono-servo Gear Gripper.
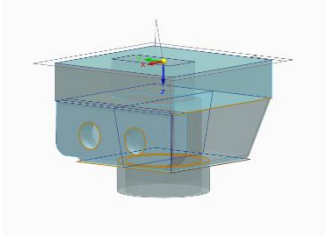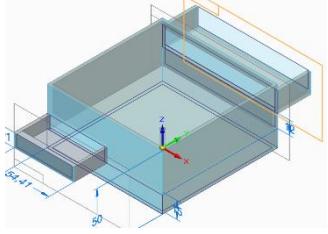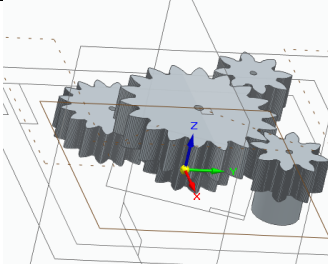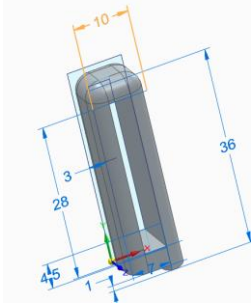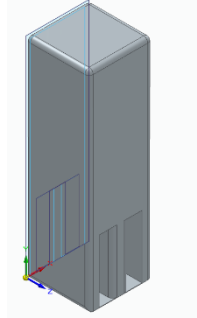

Fundamental Principle of Working

The gripper consists of a lower wrist module which contains a rectangular dead volume to house one servo motor with a microcontroller.
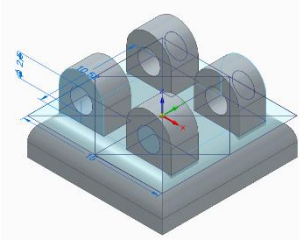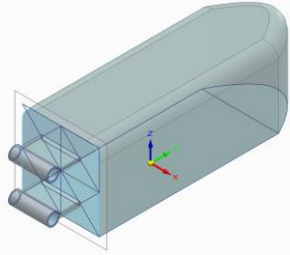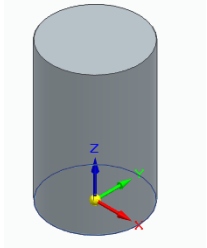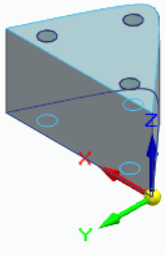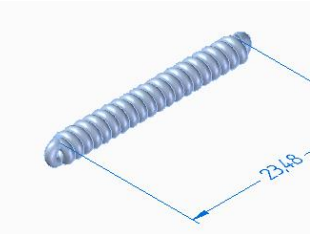
The Servomotor shaft will pass through center to the gearbox palm module where it is connected to 2 stacked gears. Refer gear layout in Gearset.

This gear mechanism transfers motion orthogonally from Beel Gear in XY plane to move the Bevel Gear & Link (Refer Parts list Below) in the YZ plane.

The RPM speed of Thumb of Gripper is not same as that of bi-fingers and thus the approach to pick up the object must start not at the origin but by some distance dev in Y' axis.

3.1.1.1: Parts List

Sr. No.	Component	Specifications	CAD
1	Wrist Module	- A space to accommodate 1 servo motor and 1 microcontroller	
2	Gearbox – Palm	- A container to accommodate gearset. - Has a center opening (4mm) to allow servo shaft to enter it.	
3	Gearset (Assembly copied as a part in final assembly)	- A combination of all spur gears - The RPM of Left Mono gear < Right Bi Gears - The Bi-Gears have 15mm Support elevation.	
4	Bevel Link	- A link with a groove. - Attached on orthogonal Bevel in the YZ plane	
5	Link 1	- A Link with a bi-groove slidable mechanism. - The groove will slide and a Pivot axle will go through the three ends.	

6	Interphalangeal Hinge	- The flat base of hinge is attached on flat base of Link 1. - The Link 2 is connected to Link 1 through this Hinge.	
7	Link 2	- The Thumb Link is connected to Link 1 through Hinge and spring mechanism through turner module.	
8	Bevel Link Extension	- A simple cylindrical depth given to support spring. - Connected on Bevel Link.	
9	Turner Module	- A 3 Pivot System to act as a thumb hinge. - One pivot on Link 1, Other 2 are connected to spring. - Each spring connected to each Link 1 and Link 2.	
10	Spring	- A spring of high spring constant value. - Generated through SolidEdge Generator.	

The Design

The Mono-Servo Gear Gripper removes expensive and complex components from the original 3 finger gripper. Firstly, 3 servos were reduced to 1 servo which transfers power to three fingers by a gear mechanism. Secondly, the complex finger pivots were replaced with a relatively simpler spring – hinge mechanism and a link-groove mechanism. Thirdly, the tactile sensors are removed, and a small camera will be placed in the gearbox closing panel (Not shown here). This camera will be connected to the cloud through IoT on microcontroller. The cloud will have a Computer Vision Model which will determine the approach of the gripper (Calculating the midpoint and distance dev according to RPM of thumb and bi-fingers) to an object and with its low latency, high bandwidth, and quickly communicate with the microcontroller to adjust its approach. This way we can use Software Capabilities to automate our Gripper instead of using expensive Tactile sensors.

Advantages

The proposed design successfully minimizes the cost and complexity of the existing 3 finger gripper. The industry-standard Tactile sensors cost $5400+ The majority Cost is removed through a simple Camera-Iot-Cloud-Ai (CICA) System. The 3 Servos further increase the weight & overall cost which is minimized by replaced one master servo.

Limitations

- The new design does not allow for different grip modes. The 3-finger gripper has 10+ different types of grips due to individual finger control. Thus, only specific dimensions of an object can be picked.
- The gearset and mechanism will have to be regularly greased to avoid heating and disfunction.
- The CV model might not correctly calculate the distance dev and this may lead to incorrect approach to object.

The Assembly

The figure alongside shows the final CAD image of the SolidEdge assembly of the Shape Memory Alloy (SMA) Gripper
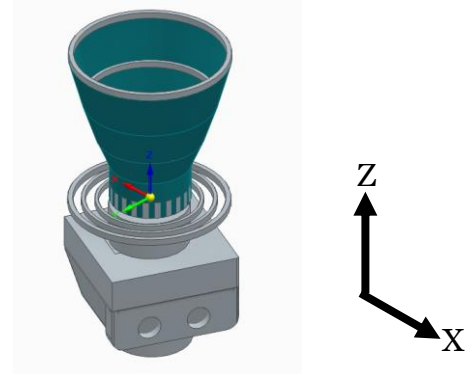
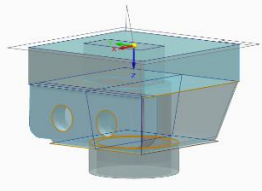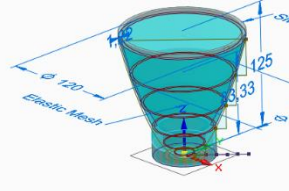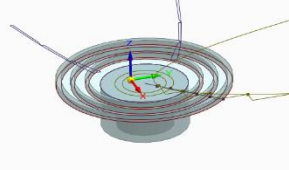## Fundamental Principle of Working

The gripper consists of a lower wrist module which contains a rectangular dead volume to house one rheostat with a microcontroller.

The rheostat controls the amount of electricity flowing to heat element source coil which helps in producing heat. This heat is passed through flat thermally conductive threads going to a heat distribution pad attached on inner surface of the Shape Memory Alloy ring on the topmost part of paraboloid gripper mesh. The heat will cause transformation of SMA ring to SMA ellipse (Based on initial settings).

The outer surface of the SMA ring will be connected to a heat sink/Cooling element which will reverse the thermal effects, thus causing SMA Ellipse to return to SMA Circle.

Several concentric NON-SMA Rings lie below the SMA Ring in decreasing radii from top to bottom. These rings are bound by an Thermoresistant Elastic Mesh Which can expand/contract when the SMA ring transforms

3.1.1.1: Parts List

Sr. No.	Component	Specifications	CAD
1.	Wrist Module	- Same as Approach 1 - The space will now be occupied by a rheostat, thermostat and microcontroller.	
2.	Paraboloid SMA Ring with Elastic Mesh Gripper	- A Circular Paraboloid when Cooled. - A non-uniform elliptic paraboloid when heated. - Elastic Mesh has a particular constant value K (Refer Mathematical Model of SMA Gripper)	
3.	Thermal Coil	- Heating Element Coil attached to the Paraboloid gripper coil. - Similar to Electric Kettle Heating Coil.	

The Design

The paraboloid gripper Module consists of one Nickel Titanium (NiTi) shape memory alloy (SMA) Ring of Diam 120mm and other 5 NON-SMA Rings as support to a paraboloid elastic mesh of a surface spring constant value less than $\frac{2\times10^6}{(Cf-0.291)}$ (Refer Mathematical Model of SMA Gripper provided In Approach 2 Folder) which encompasses this gripper. The SMA will be a circle when cooled and an ellipse when heated which is provided by thermally conductive threads from a heating element given at the bottom of the gripper. The heating element is connected to the wrist module which has a rheostat with microcontroller and power IN and communications Port. A thermoresistant insulated camera will be attached in the bottom of paraboloid gripper which will have a focused vision, employed with CICA system or a HIGH TEMP Pressure Transducer may be used instead of a Camera.
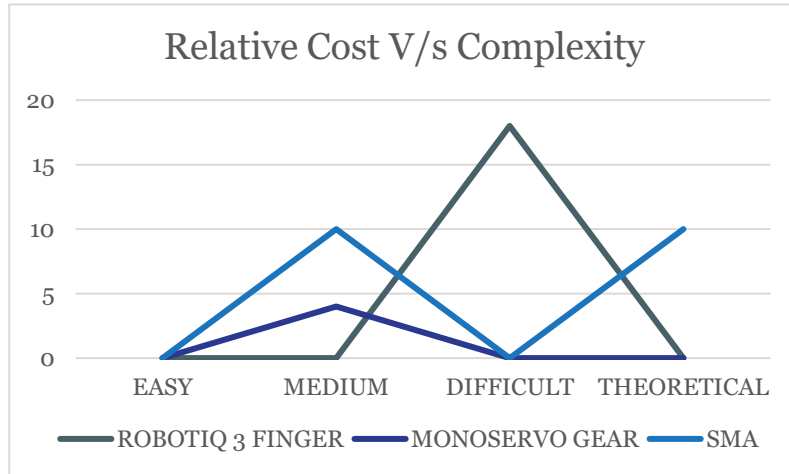
Advantages

The proposed design is a theoretical model which has not yet been employed in such a way. However, the gripper mechanism is free from servo motors and sensors and entirely relies on thermal properties of material. The Elastic mesh would allow it to expand in size when a certain object is grabbed thus object shape won't be an issue here. Also, the tensile strength of SMA are very high so grip strength as well as object pickup weight will be better.

Limitations

- The elastic mesh may not stay intact after some time leading to loss of grip and tears in grip. Also, sharp, and smaller than mesh gap objects cannot be picked.
- The design is theoretical, and its practical implementation may not be as efficient.
- The objects can only be picked from above/oblique and not from any angle.

DESIGN ANALYSIS

Relative Cost V/s Complexity

	EASY	MEDIUM	DIFFICULT	THEORETICAL
ROBOTIQ 3 FINGER				
MONOSERVO GEAR				
SMA				

3D Printing Capability

Mono-servo Gear Gripper	SMA Gripper
Yes, the body as well as the gears can be 3D printed.	Only the wrist module and non-SMA rings can be 3D Printed.