Olakunle Olukayode
Department of Mechanical Engineering
Osun State University, Osogbo
Nigeria
Department of Mechanical Engineering
Reddemer's University, Ede
Nigeria

Joshua B. Ojerinde
Department of Mechanical Engineering
Osun State University, Osogbo
Nigeria

Titus O. Ajewole
Department of Electrical & Electronic Engineering
Osun State University, Osogbo
Nigeria

Wasiu O. Adedeji
Department of Mechanical Engineering
Osun State University, Osogbo
Nigeria

Onisokumen J. Imbre
Department of Mechanical Engineering
Osun State University, Osogbo
Nigeria

Design of a PET Plastic-Loop Robotic Gripper with a Soft-Rigid Palm for Adaptive and Enveloping Grasping

Gripping of objects firmly without damage is a desired quality of a robotic gripper. Non-biomimetic grippers' design based on adjustable flexible loop capable of firm grip are yet to be widely explored in gripper design. This paper presents a 3D printed gripper design based on the grasping action achieved by holding the gasp object between a soft-rigid palm and a flexible plastic loop in tension which wrap round the object and the palm. Force analysis indicates the gripping force is proportional to the tension in the gripper's loop. The maximum payload depends on the friction coefficient at object-gripper interface and the magnitude of available gripping force. The gripper evaluation showed that the maximum loop tensile and gripping forces developed are 7.37N and 8.70N respectively. The gripper successfully demonstrated ability to grasped objects of various shapes, sizes, weights, and textures.

Keywords: *adaptive gripper, loop gripper, PET plastic, 3D printing, Non-anthropometric gripper, soft robotics,*

1. INTRODUCTION

A recent development in the field of robotic mani–pulation is the emergence of soft robotic grippers. Soft grippers are made completely or partly from soft materials. This material property enables soft grippers to adapt themselves to the gripping object thus creating a force or form closure [1-2]. These type of grippers are also very versatile when it comes to grasping objects of various shapes and surfaces and their soft nature enables a sensitive way of gripping [2-3]. In robotic object manipulation, grippers with anthropometric morphology have dominated the field due to the undying influence of the prehensile human hand as an ideal model of dexterity and functionality for robotic grippers to imitate. Human hand is characterized by its multiple degrees of freedom and multi-modal perception. Grip–pers imitating human hand are thus designed with mul–tiple fingers incorporating multiple sensors for capturing fingers' positions and forces they apply [3]. This design approach leads to the grippers' mechanisms and control systems being complex as a matter of necessity[4]. Apart from human hands, there are other sources of inspiration from nature in designing robotic gripper, such as lobster claw, bird's claw, elephant trunk and tentacles among others. Grippers inspired by nature are referred to as biomimetic grippers [5].

Robotic manipulation is important in industry, es–pecially when it applies to material handling, mecha–nical assembly, items sorting or bin picking [6] Gras–ping being a fundamental aspect of robotic manipu–lation, focus on obtaining complete control of an ob–ject's motion. A grasp is an act of restraining an object's motion through application of forces and torques at a set of contact points. A grasp is defined as being stable when the object immobility is ensured [7]. Grasp are divided into power grasp where considerations of stabi–lity and security predominate, and precision grasp where consideration of sensitivity and dexterity predominates. Power grasps involves large areas of contact between the grasped object and the surfaces of the gripper. Abilty of a gripper to hold an objects is a function of many things including friction, the texture and fragility of the object, and how well the object fits the geometry of the gripper [8]. The interaction interface between the gripper and object is the subject of grasp modelling. According to literature, there are generally three types of contact that can occur in grasping scenarios: point contact, line contact and area contact [9]. A point con–tact occurs when a single point comes in contact with another point, a line, or a plane. Line contacts occur when a line comes in contact with another line or a plane. Area contacts occur when a plane comes in contact with another plane. Plane on plane contact is regarded as the most stable of the three [4,10]. It also has the advantage of distributing contact force on wider region thereby reducing stress concentration.

As opposed to biomimetic approach to gripper de–sign, one emerging category of soft robotic gripper design is based on the idea of grasping objects via a contiguous deformable surface that encloses the grasped object without recourse to finger-like protuberances. This non-biomimetic approach is motivated by the de–sire to create grippers that can grasp and manipulates objects of diverse shapes and sizes using simple actua–tion methods [4,5,11]. Non- biomimetic grippers usually accomplish their grasping action by either enveloping the object to be grasped or by wrapping an extended structure, similar to a tendril or tentacle around the grasped object. Enveloping involve partially enclosing

Received: October 2025, Accepted: January 2026
Correspondence to: Olakunle Olukayode
Department of Mechanical Engineering,
Osun State University, PMB 4494,Osogbo, Nigeria
E-mail: olakunle.kayode@uniosun.edu.ng
doi: 10.5937/fme2601174O

an object within a three dimensional region of a soft surface. The common forms of actuation for these types of gripper are by pneumatic pressure, tendons or by tensioning of a flexible adaptive surface around the grasped object [11- 17].

Several grippers had been designed based on defor–mable one-dimensional objects like strings, ropes and cables to form adjustable loop which can be use for object's grasping. Roth *et al* [1] designed and built a soft gripper, based on adjustable threads, providing the flexibility and sensitivity needed for gripping honey–comb materials. Manes *et al.* [18] developed a prototype soft cable loop based gripper for chemistry automation tasks. The prototype gripper can reliably grasp cylin–drical and prismatic objects of various sizes as com–monly found in chemistry laboratories. The design exp–loits the inherent compliance of a cable that is driven to fully envelope the target object. The limitation of this gripper is that it was designed specifically for manipu–lation of rigid laboratoray glasswares vessels in pick and place operation. Grasping of soft or fluffy objects was not a focus and general grasping of everyday objects was not put into consideration. Another application of string loop as a gripping mechanism is in Lasso gripper [19]. The gripper was inspired by traditional horse catching tools like lasso or uurga and based on a novel string loop grasping mechanism, which gave it ability to achieve a large but adjustable initial capture range. This wide range of operation ensures the likelihood of suc–cessful grasping by the gripper. The gripper's focus on ability to grasp objects at a considerable distance from the manipulator is apt if the objects to be grasped are not easily damaged by tipping over or being dragged in the process of the lasso trying to secure a grip. More–over, loops based on strings tends to create stress concentration lines along its' interface with the grasped object. This stress lines has tendency to concentrate gripping force over a relatively smaller area that may damage delicate objects hence the need to explore the use of a relatively wider strip materials for the loop in other to distribute stress over a wider surface area of gripper-object interface. Line on plane contact being less stable than plane on plane [10], the loop will have a better stress distribution on objects-gripper interface if made from wider strip of material rather than being fashioned from strings. Thus this paper aims at developing a novel loop gripper with 3D printed body, utilizing a flexible plastic strip formed into a loop and in conjunction with a high density foam pad palm with capability for grasping objects with varying sizes, weight, texture and shapes rather than for a specific grasp application.

2. MATERIAL AND METHOD TO DESIGN THE LOOP GRIPPER

2.1 Working Principle

The mechanical design of a robotic gripper is a critical aspect in the field of robotic arm or manipulator development where gripper is referred to as an end effector. Gripper must possess the versatility to handle object of various types, from delicate items to heavy objects. It should provide secure and stable grasping actions while reducing the risk of damage to the object being grasped [20].

The manipulation of an object is divided into 6 stages: approaching, coming into contact, increase of the force, securing, moving, and releasing [21,22] Research in grasping in robotic gripper design usually focus on coming into contact, increasing the grip force, and securing stages [21]. The sequence of actions of the plastic loop gripper in grasping is similar to that of [18]. However, unlike in the work of [18] a wide strip of inelastic but flexible plastic material forms the loop rather than a string and attention is also given to the role of the palm (referred to as finger in their design) in grasping an object. For this present gripper, the working principle is as follow (Figure 1); (a) the plastic strip that form the loop has one end of it fixed to the back (A) of the soft-rigid palm and is expanded by pushing the free end of the loop from back of palm (B) until the loop diameter is larger than the object to be grasped. Then the gripper is moved until it is positioned above the object. (b) The gripper is then lowered until it encompasses the object. Once properly positioned, the enveloping action begins with the initiation of pulling force (wide black arrow) on the free end of the loop. (c) The pulling force continues to be active (wide black arrow) until it had secured tightly the object to the palm soft pad. (d) with the object secured, the gripper is then able to lift the object. The largest graspable object size is determined by the gripper loop's maximum aperture.

2.2 Force Analysis

The force analysis diagram for the grasping process of the soft gripper is illustrated in Figure 2. The object to be grasped is constrained in the vertical plain (along z axis) from sliding down under its own weight (Mg) by friction force f, the object is made to hug the palm by the loop which is under tension T thus developing a reaction or gripping force R.

For the vertical plane (along Z axis):

$$Mg = 2f \tag{1}$$

where M is the mass of the object to be grasped, g is acceleration due to gravity. For the horizontal plane:

$$R = 2T\sin\theta \quad \text{(X axis direction)} \tag{2}$$

$$TCos\theta = T\cos\theta \quad \text{(Y axis direction)} \tag{3}$$

R is the minimum gripping force the loop must exerted to hold the object being grasped. θ is the angle between the loop and the surface of the gripper's palm. It should be noted that the value of θ depends on the width of the palm as well as the maximum distance (d) between the pad and the strip which depends on the size of the gras–ped object.

$$f = \mu R \tag{4}$$

where μ is the coefficient of static friction between the object and the palm/strip.

Combining Equations (1) and (4),

$$M = 2\mu R/g \tag{5}$$

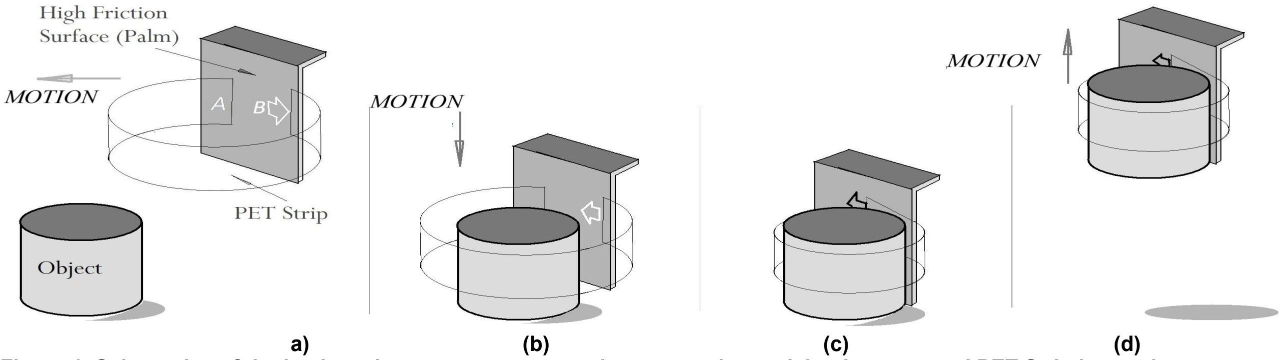


Figure 1. Schematics of the basic action sequence to complete a grasping task by the proposed PET Strip loop gripper

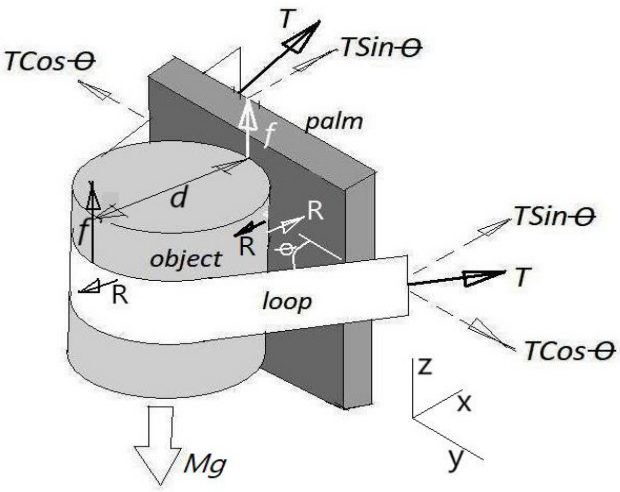


Figure 2. Force analysis diagram

Thus the gripper payload capacity is dependent on the gripping force and coefficient of friction between the grasped object and the gripper contact surface.

Substituting Equation (2) in (4);

$$f = 2\mu \mathrm{T}\mathrm{Sin}\theta \quad (6)$$

Substituting Equation (6) into (1);

$$Mg = 4\mu TSin\theta \quad (7)$$

$$T = Mg/4\mu Sin\theta \quad (8)$$

Equation (8) revealed that tension T require for the loop to grip a particular payload is directly proportional to the mass M of the grasp object and inversely propor– tional to the coefficient of static friction between the object and the gripping surface as well as angle between the strip and the palm surface. Thus, the bigger the dia– meter of the object the greater the magnitude of θ. With respect to θ, T is at minimum when θ is equal to 90^o. This situation occurred when the horizontal extent of the grasp load equal the width of the palm. Thus a higher coefficient of static friction and a large dimension object will require a relatively lesser tension force for grasping as compare to a lower coefficient of static friction and a smaller dimension object weight for weight.

In term of the gripper payload shapes, the natural shape of gripping objects is cylinderical based on the shape of the loop formed. However the gripper is ex— pected to be able to grip non-cylindrical shaped objects due to the flexibility and the enveloping action of the PET loop.

2.3 Proposed gripper concept and actuation mechanism

The novelty and the scientific merit of this concept gri– pper compared to similar grippers from literature that are based on sring loop are as follows: rather than utilizing string or thread to form the loop, which is a form of line (the loop) on plane (the object) gripping mode, a rela– tively wider strip of material is adopted in order to achi– eve a plane on plane gripping mode. The plane on plane gripping contact, as previously mentioned, is the most stable form of grasp model. Moreover, line on plane gripping model like point on plane model tends to create streess concentration spots. In contrast plane on plane favours stress distribution. This ability to distribute stre– sses over a relatively larger surface is most relevant when grasping frigile and easily difformable objects that are sensitive to grip force in order to prevent damage .

Another uniqueness of the gripper is in the material selected for the gripper's loop. Polyethylene Terepht– halate plastic is a very common and inexpensive mate– rial. When cut into strips and formed into a loop, its loop has a level of shape rigidity which string or thread loops lack since they tend to be floppy. As used in this gripper, the plastic strip does not need any further intrinsic modification. Its ability to form a rigid loop is very important when positiong the loop over the object to be gasped which will be relatively more difficult for floppy string based loop gripper.

Moreover, in order to further increase contact area between the gripper and the grasp object, provide cushioning effect on the object and increase friction between object and gripping surface, a soft-rigid palm is incorporated with the loop. The soft part which is to be in contact with the grasp object must possess a high coefficient of friction which is important in reducing the gripping force required to grasp the object. Additionally, using the loop in conjuction with the palm will have tendency to reduce the grasp object's side-sway during robotic arm manipulation when compared to using the loop alone. For context, in the loop gripper developed by [18] the loop pulled the object to hug a rigid finger.

Another important requirement is that the gripper must be able to hold object even when power supply is cut off. This requirement is made posible with the use of a geared motor as the actuator which supply high torque at its output shaft and conversely also required high torque to manually rotate its spindle in reverse. Thus when an object had been gripped, there is less likelyhood of the reaction force of the object against the loop's contraction round it to supply enough reverse torque to turn the motor spindle and release the object.

Based on the aforementioned design considerations, the concept for the gripper is as presented in Figure 3. The flexible plastic strip that forms the loop is assumed to be inelastic, but flexible and rigid enough to allow for push/pull action by the spool. The spool is rotated by the geared direct current (DC) motor housed in the motor housing and directly coupled to the spool shaft. When the motor rotates the the spool in the clockwise direction, this rotation pushes out the PET strip thereby increasing the aparture of the loop. Once the diameter or the loop's aparture is big enough, the loop is placed round the object to be grasped. The polarity of the DC motor current supply is then reversed and the spool rotates in the counter-clockwise direction thereby pulling in the loop. This action continues until the loop had firmly made the object to hug the soft-rigid palm. With the object secured, the robotic manipulator arm to which the gripper is attached (not shown) can then manipulate the object. To release the object, the motor rotates the spool again in the clockwise direction thereby expanding the loop until the object is released. At the heart of the gripper actuation mechanism is the N20 gear motor micro metal model NFP-GM12-N20 with the following specifications; 3V DC, 0.3 W (max.), speed reduction ratio 210:1, 0.50kg.cm rated load torque and 1.50kg.cm stall torque (www.microdcmotors.com).

2.4 Gripper Materials, Fabrication and Assembly

In the design of flexible and adaptive soft-robotic grip–ping systems, materials with a small Young's modulus are used in order to be risk-free in interaction with hu–mans. Desirable properties from such materials include suitability for easy processing, light weight, high tough–ness, and excellent ductility as well as a high load capacity. In addition, the materials, especially the one that will be in direct contact with the object to be grasped must have sufficient flexibility that will enable it to adapt to the topology of the object [23]. The prototype gripper incorporates three key materials for its components' fabrication: Polyethylene Terephthalate Glycol-modified (PETG) for the gripper body (gray colour parts in Figure 3), Polyethylene Terephthalate (PET) for the loop (Purple colored part) and high den–sity Ethylene-Vinyl Acetate (EVA) foam for the soft part of the palm (red colored part).

PETG with density 1270 kg/m^3 is a tough and du–rable plastic material that is water proof, chemically non-reactive and with high impact resistance. The typi–cal values for its tensile strenght, flexural strenght and flexural modulus are 53, 58 and 1073 MPa respectively (PETG Technical Data Sheet, www.esun3d.com). PET plastic on the other hand is a strong, lightweight and transparent recyclable polymer widely used in food (for bottles, food packaging) and textile (for textile fibres) industries [24]. It is known for its good chemical, sol–vent and wear resistance. Typical values for its tensile strength, tensile modulus and bending modulus are 57, 2420, and 2400 MPa respectively (PET Technical Handbook, www.ecoease.co.uk). EVA foam is a closed-cell lightweight, and durable foam known for its flexi–bility, resistance to water and cracking as well as good shock absorption properties [25].

The loop was made from strips cut from 0.5mm thick flexible PET sheet (www.desuplastic.com). The palm soft pad was cut from a high density (180 kg/m^3) EVA foam 10 mm thick (Shanghai Ruchen Ind. Co. Ltd., China). The rest of the gripper body was 3D printed on Creality Ender 3 Pro 3D printer (Figure 4) using 1.5mm PETG filament (www.cc3dglobal.com). The rigid palm, the spool, the pod and the pod cover were 3D printed separately with a 100% infill density and joined together (except the spool) to form a single gripper body using adhesive at the joints. The basic dimensions and other parameters of the gripper are listed in Table 1. The manufacturing parameters for 3D printing of the gripper body are summarized in Table 2. All the working and assembly drawings for the gripper were done using *SolidWorks,* a computer-aided design software for solid modelling.

Table 1. Characteristics of the loop gripper

Rigid palm length	145 mm
Rigid palm width	68 mm
Palm pad width	60 mm
Palm pad length	120 mm
Palm pad thickness	10 mm
Loop maximum approximate aperture size (PET at strip max. extension)	90 mm
Loop PVC strip thickness	0.5mm
Loop PVC strip width	25 mm
Spool mean diameter	40 mm
Maximum object diameter which can be grasped	<90 mm
Total mass of gripper body (motor, PET strip and PVC pad inclusive)	173 g
Friction coefficient, Soft palm vs PET (experimentally determined)	0.49
Friction coefficient, PET vs PET (experimentally determined)	0.30

Table 2: Parameter settings for the 3D printing of the gripper body

Parameter	Value
PETG Filament (CC3D)	100%
Infill pattern	Grid
Extrusion width	0.4mm
Extruder temperature	245^{o}C
Perimeter shell	1.5mm
Layer height	0.2mm
Heated bed temperature	80^o C
Printing speed	50mm/s

The assembly procedure for the gripper is illustrated in Figure 5a: the soft EVA foam pad (1) is attached to the surface of the rigid palm (2) using an adhesive. The end A of the PET strip (3) is attached to the spool's barrel (4) using a pair of M3 flat-head wood screws. Next, the PET strip is wound round the spool in the clockwise direction. With the strip held in place manually, the free end B is passed through the slot (6) on the spool pod (5) from inside to the outside. Then the longer (lower) end of the spool's shaft is inserted into the shaft's support integral to the floor of the spool's pod.

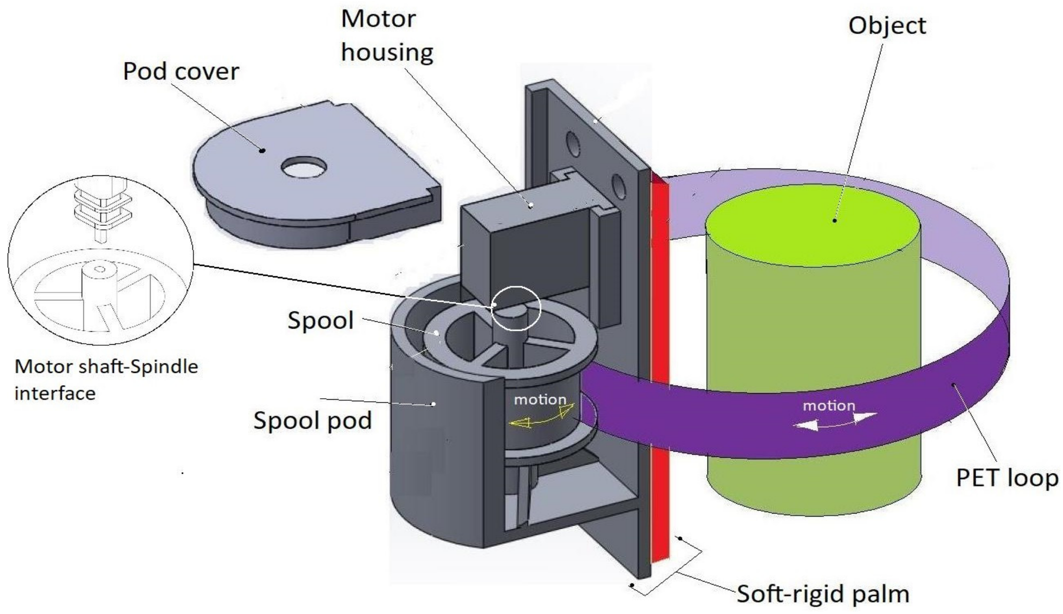


Figure 3: Cut-away view of the concept gripper

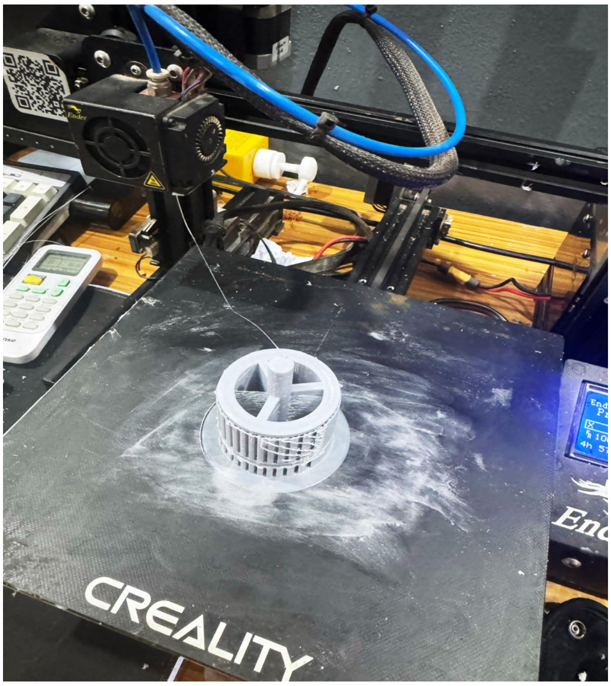


Figure 4: 3D printing of the spool on *Creality 3D Printer*

The free end B of the strip is then inserted to the other slot (7) on the spool pod from outside to the inside and held in place through the use of a plastic wedge (8). This procedure forms the PET strip into a loop. The cables of the geared DC motor (10) are passed through the hole (11) on the motor housing (12). Then the motor is inserted into the hollow space provided for it in the housing in the direction of the arrow. The pod cover is placed over the pod with the shorter (upper) end of the spool shaft protruding through it. After this, the motor/ housing sub-assembly is attached to the back of the rigid palm by pushing it though the guide rails (13) integral to the palm. The shaft should align with the center of the spool shaft hole (15). It should be noted that the hole's cross-section in shape of letter D is the same as that of motor shaft cross-section (see Figure 3, inset). This is to create a positive mechanical lock between the motor shaft and the spool shaft. Once aligned the motor housing is pushed downward until motor shaft engaged the spool shaft. Figure 5b is the picture of the gripper when assembled (with pod cover removed in order to shown the spool in position). Holes C and D on the gripper are provided as means of fastening it to a robotic manipulator.

3. GRIPPER EVALUATION TESTS , RESULTS AND DISCUSSION

To evaluate the effectiveness of the developed loop gripper, the following three experiments were conducted: (i) operational voltage versus loop tensile force test (ii) grasping force test and (iii) object grasping experiment.

Operational voltage versus loop's tensile force test

The power drawn by a motor is a function of the supplied current and its voltage. By varying the voltage of the electricity supply to the motor, its power output is varied accordingly. This translates also to the variability of the developed torque and rotational speed of the motor shaft**.** When used to retract the loop strip to close the loop aperture around the object in grasping mode, a tensional force is developed in the strip as a result of being pulled in by the spool which in turn is rotated by the motor.

This experimental is set-up to test the maximum tension the geared motor can exert at several operational voltages on the loop strip as shown in Figure 6a. The push/pull gauge (Hojila, USA) has maximum force range value of 50N with ±1% accuracy, while the voltage regulator (PS-1501S, Best(R), China) has voltage range 0 - 15 V DC. The motor voltage levels were varied at 0.5V intervals from 1 to 3V. The correspondent peak tensional force in the strip was recorded. The variation of the tensile force developed in the PET strip and the motor voltage is as shown in Figure 6b.

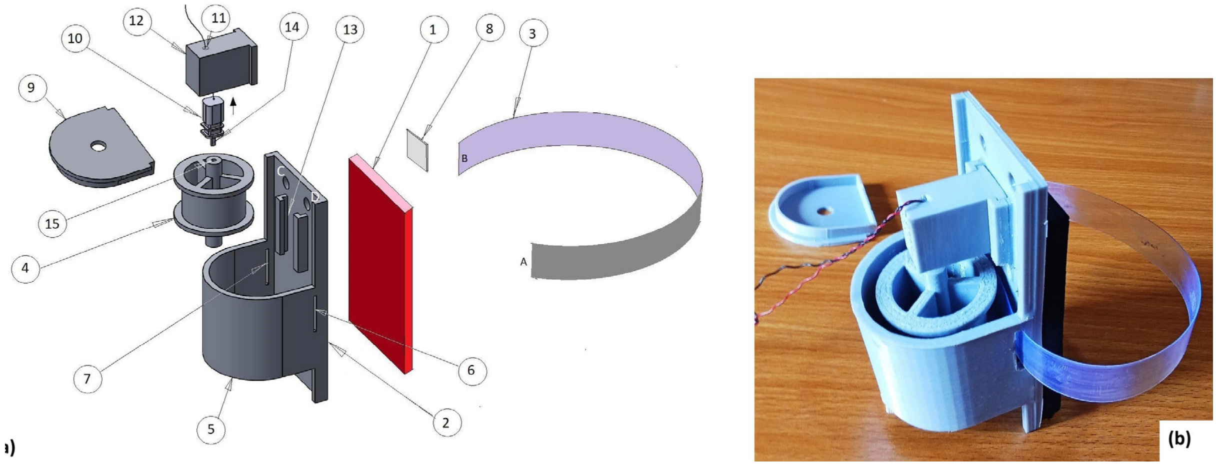
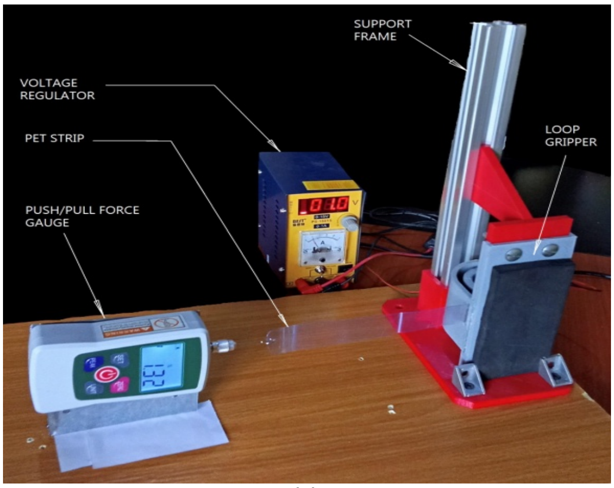
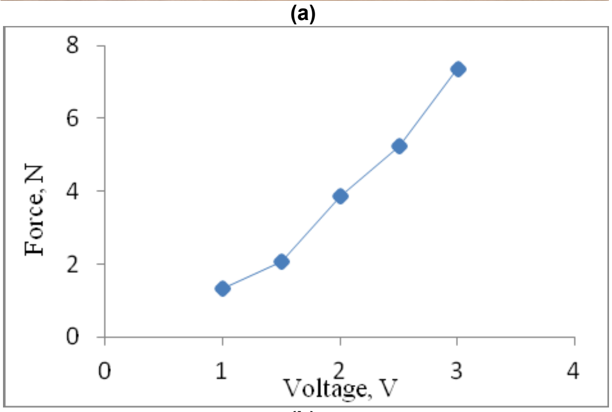


Fig. 5 Loop Gripper Mechanism CAD design Exploded view (a), Assembled Loop Gripper with the pod cover remover to show the spool in position (b)



(a)

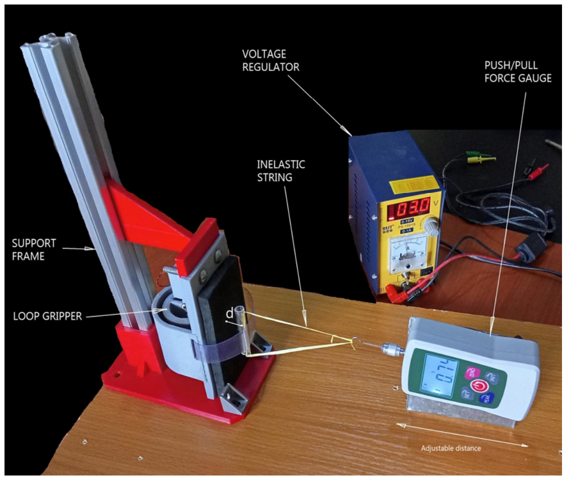


(b)

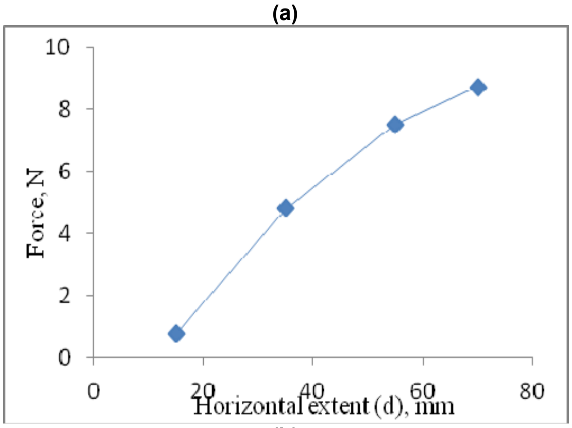
Figure 6. Experimental set-up for operational voltage ver– sus loop's tensile force test (a), and relationship between voltage and loop's tensile force (b)

Gripping force test

The griping force test was conducted using the experimental setup depicted in Figure 7a. The distance d (gap distance between palm and loop) is varied to simulate the payload size. Since d determines angle θ, this test is a validation test for Equation (2). Distance d was varied for four intervals 15, 35, 55, and 75mm. The pull force (i.e. the grip force) by the loop was gradually increase by increasing the voltage to 3.0V, the maximum operational voltage for the motor. The maximum pull at this voltage is read off the push/pull gauge. The voltage is then gradually reduced to zero and the process repeated two more times. The average grip force for the distance d is then recorded.



(a)



(b)

Figure 7. Experimental set-up for gripping force test (a) and relationship between grip force and gap distance between palm and loop (b)

The relationship between d and the averaged deve– loped pick gripping force is as shown in Figure 7b. The results shows that as distance d increases, the grasp force also increases. At 75mm extent, the gripping force value is 8.7 N. The grasp force developed by the gripper is within the range observed for soft robotic biomimetic and non-biomimetic grippers of similar size [26-29].

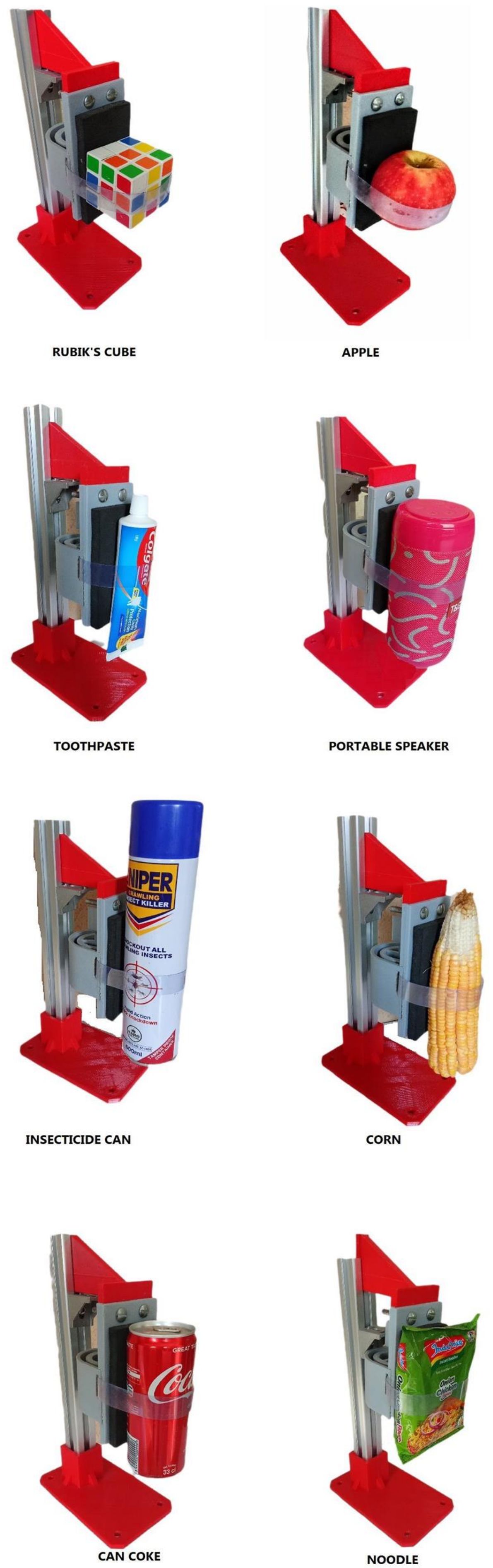


Figure 8. The loop gripper holding up various objects

Objects grasping experiment

The aim of this experiment is to demonstrate the prac–tical applications of the gripper in order to shows its industrial relevance. The designed loop griper grasping capability was evaluated using 10 objects of various shapes, sizes, weights, and textures. The objects selec–ted were ensured to have horizontal extent not more the 85mm due to the constraint placed by the maximum loop aperture size of 90 mm the gripper can deploy. The test on each object was conducted in the sequences outline: (i) manually insert the test object from beneath the loop and into the encompassing space inside the loop, (ii) operate the gripper to close the loop to grab the object;(iii) hold the object for 15 seconds, (iv) then relax the loop to release the object. The physical properties of the test objects were as displayed in Table 3. Figure 8 shows the gripper holding up the various test objects. Grasping is deemed successful if no slippage of the object occurred within the 15 seconds period. The maximum test object weight successfully grasped by the griper was 407 g portable speaker with diameter 70mm and length 170 mm.

Table 3. Properties of the test objects used in the gripping test.

Object	Weight (g)	Dimension (mm)*	Gripping success
Rubik's Cube	51	56 x 56 x 56	Successful
Apple	171	74	Successful
Toothpaste	156	35 x 160	Successful
Portable speaker	407	70 x 170	Successful
Insecticide can	365	65	Successful
Corn	214	52 x 180	Successful
Coke can	356		Successful
Noodle	79	90 x 30 x 120	Successful
Bottled water (pet bottle)	769	70 x 230	Unsuccessful
Fruit juice (pet bottle)	618	60 x 230	Unsuccessful

**for dimensions of cuboids objects, width, breadth and length were specified, for cylindrical ones, maximum diameter and the height, and for spherical ones, diameter*

Attempt to gasped bottled water and bottled fruit juice of mass 769 and 618 g respectively was unsuc–cessful despite similarity of diameter to the portable speaker (Table 3). This limit is reasonable due to the fact that the maximum grip force experimentally deter–mined for the gripper at 3V power rating was 8.70 N with average coefficient of friction between the grip–per's palm and PET (the bottle material) of 0.49 (Table 1; Equation 5 refers). It was also observed that the apple and the corn did not shows any visible dent or abrasion on their surfaces thus lending credence to the stress distribution nature of using PET plastic strip as oppose to string in forming the gripper's loop. The developed gripper can only grasped object less than 90 mm in diametric extent due to the limitation imposed by the gripper's loop aperture, it compensated for this limi–tation by being able to grasp objects of various shapes due to the loop's adaptability. The gripper is scalable in term of payload capacity. This is achievable by using a higher power rating motor and by using loop and soft palm materials of higher coefficient of static friction. The weight and diversity of objects graspable by the gripper is similar to those used in testing similarly sized soft biomimetic and non bio-mimetic grippers [27–30].

4. CONCLUSION

In this study, a non-anthropometric, non-biomimetic gripper using a soft rigid palm in conjunction with an adjustable loop formed by a PET plastic strip as its grasping mechanism was developed. Analysis shows that increasing the gripper actuator motor power as well as coefficient of static friction between the gripper and the grasped object contact surfaces will increase the gripper's payload capacity. This demonstrates the scalability of the gripper for greater payload capacity. Experimental results show that the gripper can grasp objects of various shapes, sizes and texture by enveloping them in-between the loop and the palm. The gripper is easy to fabricate and it was intentionally designed for ease of assembly. Finally, the merit of this gripper lies in its simplicity of design and assembly, good adaptability to objects of various shapes and sizes, its ability to provide firm grip without damaging the gasp object either through crushing or cutting, object holding capacity even when the power supply is cut-off and shape rigidity of the gripper's loop which reduces the need for high positioning accuracy when positioning the loop over the object to be grasped.

ACKNOWLEDGEMENT

We acknowledge the effort of Ayodeji S. Fadayo of the Department of Mechanical Engineering, Osun State Universty, Osogbo, Nigeria as regard the 3D printing of the gripper body on Creality Ender 3 Pro 3D printer.

REFERENCES

[1] Roth, F., Eschen, H., Schuppstuhl, T. The loop gripper: A soft gripper for honeycomb materials. 30th International Conference on Flexible Automa–tion and Intelligent Manufacturing (FAIM2021) 15-18 June 2021, Athens, Greece. *Procedia Manufac–turing*, Vol 55, 2021, pp 160 – 167

[2] Laschi, C., Mazzolai, B., Cianchetti, M., Soft robo–tics: Technologies and systems pushing the boun–daries of robot abilities, *Science Robotics* 1 (1) (2016) eaah3690

[3] Shintake, J., Cacucciolo, V., Floreano, D., Shea, H. Soft Robotic Grippers. Adv. Mater. 30, 1707035. (2018). doi:10.1002/adma.201707035

[4] Hao Y., Visell Y. Beyond Soft Hands: Efficient Grasping With Non- Anthropomorphic Soft Grip–pers. Front. Robot. (2021) AI 8:632006. doi: 10.3389/frobt.2021.632006

[5] Cairnes, T.J., Ford, C.J., Psomopoulou, E., Lepora, N. An Overview of Robotic Grippers. arXiv: 2304.14051v1 [cs.RO] 27 Apr 2023

[6] Phan, D. C., Ngo H. Q. T. Robotic Manipulation via the Assisted 3D Point Cloud of an Object in the

Bin-Picking Application. *FME Transactions* (2025) 53, 299-312

[7] Cordella, F.. Zollo, L., Salerno, A., Accoto, D., Guglielmelli, E. and Siciliano, B. Human Hand Motion Analysis and Synthesis of Optimal Power Grasps for a Robotic Hand. International Journal of Advanced Robotic Systems, 2014, Vol. 11, No 1:1. Doi 10.5772/57554

[8] Mark R. Cutkosky and Robert D. Howe . ‘‘Human Grasp Choice and Robotic Grasp Analysis’’, in ST Venkataraman, T. Iberall, editors, Dextrous Robotic Hands, Springer-Verlag, 1990, Chapter 1, pp 5-31

[9] Khurshid, A., Ghafoor, A., Malik, M.A., Robotic grasping and fine manipulation using soft fingertip, in: Advances in Mechatronics, Martinez-Alfaro, H., Ed. IntechOpen. (2011) Doi:10.5772/23697

[10] Bui, S.T., Kawano, S., Ho, V.A. Rose: Rotation-based Squeezing Robotic Gripper towards Uni–versal Handling of Objects. Robotics: Science and System XIX Conference 2023., Daegu, Rep. of Korea, July 10-14, 2023. arXiv:2402.06906v1 (www.roboticproceedings.org/rss19/index.html)

[11] Hao ,Y., Biswas , S., Hawkes, E.W., Wang, T., Zhu, M., Wen , L., and Visell, Y. A Multimodal, Enveloping Soft Gripper: Shape Conformation, Bioinspired Adhesion, and Expansion-Driven Suc–tion. *IEEE Transactions on Robotics*. Vol. 37, no. 2, pp350-362, April 2021. DOI 10.1109/TRO. 2020.3021427

[12] Hao ,Y., Wang, Z., Zhou, Y., Zhou, W., Cai, T., Zhang, J., Sun, F. A Soft Enveloping Gripper with Enhanced Grasping Ability via Morphological Adaptability. *Advance Intelligent System.* 2023, 5, 2200456

[13] Navas, E.; Fernández, R.; Sepúlveda, D.; Armada, M.; Gonzalez-de-Santos, P. Soft Grippers for Auto–matic Crop Harvesting: A Review. Sensors 2021, 21, 2689. https://doi.org/10.3390/s21082689

[14] Li, S., Stampfli, J. J., Xu, H. J., Malkin, E., Diaz, E. V., Rus, D., et al. (2019). A Vacuum-Driven Ori–gami "Magic-ball" Soft Gripper. In 2019 IEEE Int Conf Robotics and Automation; May 2019; Mont–real, QC, Canada. 7401–7408. doi:10.1109/ICRA .2019.8794068.

[15] Yamada, K., Mitsuda, T. A Vacuum□driven rubber□ band gripper. *Robomech J,* Vol. 8, No.16,pp1-12, 2021

[16] Olukayode, O., Alawode, K.O., Ajewole, T.O. and Adedeji, W.O. Design and analysis of a novel light-weight, linear actuator driven flexible PET strips robotic gripper. *UNIOSUN Journal of Engineering and Environmental Sciences*. Vol. 5, No 1, pp 85-97, 2023

[17] Xu, Z., Shi, W., Zhao, D., Li, K., Li, J., Dong, J., Han, Y., Zhao, J., Bai, Y. Research progress on low damage grasping of fruit, vegetable and meat raw materials. *Foods* 2023, 12, 3451. doi.org/10.3390/ foods12183451

[18] Manes, L., Fichera, S., Fakhruldeen, H., Andrew I. Cooper, A.I., and Paoletti, P. A soft cable loop ba–sed gripper for robotic automation of chemistry. Scientific Reports (2024) 14:8899 https://doi.org/ 10.1038/s41598-024-59372-1

[19] Qiao, Q., Wang, Y., Fan, X., and Lu, P. Lasso Gripper: A String Shooting–Retracting Mechanism for Shape-Adaptive Grasping. arXiv:2506.14163v1 [cs.RO] 17 Jun 2025

[20] Nguyen, T.T., Nguyen, T.H., Ngo, H.Q.T. Investi–gation on the Mechanical Design of Robot Gripper for Intelligent Control using the Low-cost Sensor. *FME Transactions* (2023) 52, 12-28

[21] Fantoni, G., Santochi, M., Dini, G., Tracht, K., Scholz-Reiter, B., Fleischer, J., Lien, T.K., Seliger, G., Reinhart, G., Franke, J., Hansen H. H., abd Verl, A. “Grasping devices and methods in auto–mated production processes,” *CIRP Ann. − Manuf. Technol.*, vol. 63, no. 2, pp. 679−701, 2014

[22] Fan, S., Gu, H., Zhang, Y., Jin, M., Liu, H. Rese–arch on adaptive grasping with object pose uncer–tainty by multi-fingered robot hand. International Journal of Advanced Robotic Systems. Mar. –Apr 2018, pp1-16

[23] Müllera, A., Aydemira, M., Gloddea, A., Dietricha, F., Design Approach for Heavy-Duty Soft-Robotic-Gripper. 30th CIRP Design 2020 (CIRP Design 2020) Procedia CIRP 91 (2020) 301–305)

[24] Welle, F., The Facts about PET. www.petcore-europe.org (access, 21/07/2025)

[25] Damao (2025). Understanding EVA foam density and hardness: Shore A/C explained. www.damao-tech.com (access, 21/07/2025)

[26] Zhang, Z., Zhou, J., Yi, B., Zhang, B., Wang, K. A flexible swallowing gripper for harvesting apples and its grasping force sensing model. *Computers and Electronics in Agriculture* 204 (2023) 107489

[27] Fu, J., Yu, Z., Guo, Q., Zheng, L., Gan, D. A variable stiffness robotic gripper based on parallel beam with vision-based force sensing for flexible grasping. *Robotica* (2023), 1–19 doi:10.1017/S0 26357472300156X

[28] Peng , J., Li, W., Liu, L., Liu, W., Han, Y. Design, Perceptual Modeling, and Grasping Performance Evaluation of Multibranch Flexible Grippers. *IEEE Transactions on Instrumentation and Measurement*, Vol. 74, 2025. 7500918

[29] Liu C., Maiolino, P., You Z., A 3D-Printable Robotic Gripper Based on Thick Panel Origami. *Front. Robot. AI* 8:730227. (2021) doi: 10.3389/ frobt.2021.730227

[30] Guo, C., Zhang, S., Yang, Y., Cheng, G., Ding, J. A novel soft end effector with active palm and fingertips for robotic picking. *Proc IMechE Part C: J Mechanical Engineering Science*, 2022. pp 1–12. DOI: 10.1177/09544062221144548

ДИЗАЈН РОБОТСКОГ ХВАТАЉКА СА ПЕТ ПЛАСТИЧНОМ ПЕТЉОМ И МЕКО-КРУТИМ ДЛАНОМ ЗА АДАПТИВНО И ОБУХВАТАЈУЋЕ ХВАТАЊЕ

О. Олукајоде, Џ.Б. Оџеринде, Т.О. Аџеволе, В.О. Адедеџи, О.Џ. Имбре

Чврсто хватање предмета без оштећења је жељени квалитет роботског хватаљка. Дизајн небиомиметичких хватаљки заснован на подесивој флексибилној петљи способној за чврсто хватање још увек није широко истражен у дизајну хватаљки. Овај рад представља 3Д штампани дизајн хватаљке зас–нован на акцији хватања која се постиже држањем предмета између меко-крутог длана и флексибилне пластичне петље под затезањем која се обавија око предмета и длана. Анализа силе показује да је сила хватања пропорционална затезању у петљи хватаљке. Максимални терет зависи од коефицијента трења на интерфејсу предмет-хватаљка и величине расположиве силе хватања. Евалуација хватаљке је показала да су максималне развијене силе затезања и хватања петље 7,37 N и 8,70 N респективно. Хватаљка је успешно показала способност хватања предмета различитих облика, величина, тежина и текстура.