Design and Selection of Rapid Prototyping Method and Material for Three Fingered Grippers and Printing Time and Cost Estimation

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Abstract: The objective of the proposed project is to build a Flexible Robotic Arm that has the capability to mimic the motion of a snake such that work space of the robotic arm is maximized.In the proposed project we are trying to achieve maximum mobility of the Robotic Arm such that it can pick up things placed in very complex scenarios without disturbing the scenario itself. This Snake like Robotic Arm has kinematic redundancy, like that of a human arm that enables us to place objects in various orientations. This Robotic arm is equipped with a three fingered gripper that provides for efficient grasping and controlled maneuvering through complex scenarios, providing a great challenge to the controller as well as the designer of the robotic arm.The designing of the Robotic arm and various types of Three Fingered Gripper is done in AUTODESK FUSION360 and Rapid Prototyping is done by JULIA+ Desktop 3D Printer.

KEYWORDS:Challenges, gear train mechanism, 3D printing.

DOI of the Article: https://doi.org/10.46501/GIETME14

To Cite this Article: Veera Raju P; Vasu G; Sai Kumar MVV; Satya Sai K and Jagadeeshwararao J. Design and Selection of Rapid Prototyping Method and Material for Three Fingered Grippers and Printing Time and Cost Estimation. *International Journal for Modern Trends in Science and Technology* 2021, *7*, pp. 84-91. https://doi.org/10.46501/GIETME14

Article Info. Received: 12 June 2021; Accepted: 16 July 2021; Published: 20 July 2021

INTRODUCTION:

Robotics is a mixture of geometric transformations, control theory, stepper / DC motors, digital signal processing and a real-time operating system. Robot is a reprogrammable and multifunctional manipulator designed to move materials / pieces from one place to another through different movements programmed to perform a series of tasks and the robot can also be classified according to its application method as a way of control, operating parameters, environmental conditions, structural design, structure materials, technology level. The two main types of control are servant and non-servant. The robot path can be continuous or point-to-point. The volume of the work space of a robot can be articulated in a rectangular, cylindrical, spherical or spherical shape. Human works have always been associated with the acquisition of specific skills, talents and methods and experiences. The growing competition of industrial robots for tasks normally performed by human hands has led to the need for more efficient handling equipment, in particular pre-tensioning instruments (more commonly called clamps). Finally, a robot can be classified as low, medium or high technology depending on the number of axes and the level of sophistication with respect to the effectors and terminals. The clamp is similar to the human hand when the hand grasps the tool to perform the work the clamp holds and fixes the robot's work piece while the operation is being performed. This is one of the reasonswhy tweezers deserve special attention. However, industrial robots are not simply a substitute for people often in applications beyond the normal (physical or temporary) capacity of conventional labor.

Problem Statement

A Flexible Snake like Robotic Arm is to be designed having multiple degrees of freedom, which provides for operations such as picking and placing, mating and de-mating of cables etc. incomplexscenariosinvolvingmanytwistsandturns.This armhastobeequippedwithan intelligent gripper which provides for force feedback and auto adjustment of the gripper to enhance the grip over the objects.

Objective

Among vast robotics research directions, academic research on robotic grasping and object manipulation have gained significant attention in recent years due to the increased development and commercial deployment of industrial and service robots [5]–[8]. However, majority of researchers working in this direction do not have mechanical engineering background and, hence, tend to utilize commercially available robot-manipulators equipped with various end effectors for experimental studies. Anthropomorphic robotic hands are widely used for research related to human like grasping and object manipulation where reproducing the human hand functionality is required [8]–[12]. On the other hand, three-finger grippers with relatively simple designs are sufficient to conduct research activity and educational process on manipulation of objects in industrial and service applications [6], [13]. Examples of such gripper designs are a three-finger concentric gripper [14] designed for relatively high payload industrial applications, a reconfigurable gripper [15] with convex shape thin fingers designed for picking and placing round objects, and an adaptive three-finger robot gripper [16] for use in unstructured industrial applications.

RELATED WORK

Majid Tolouei-Rad et al [1] described that industrial robots become useless without end-effectors for many instances are in the form of friction grippers. Usually friction grippers concern frictional forces to different objects on the basis of programmers' experience. This puts a limitation on the effectiveness of gripping force that may result in unclamping of damaging an object. It described the various stages of design and development of a low cost sensor-based robotic gripper that would facilitate the task of applying right gripping forces to dissimilar objects. The gripper is also set with range sensors in order to avoid collisions of the gripper with the objects handled. Gripper is entirely well designed automatic pick and place gripper which can be used in many industrial applications like all automobile industries. This may be induced for further altered or developed in order to suit a better number of industrial activities.

Redwan Alqasemi et al [2]designed and constructed a new robotic gripper for Activities of Daily Living (ADL) which is used with a new wheelchair mounted with a robotic arm and some of the sensible sensors developed at University of South Florida. This kind of new gripper made it as unique by two aspects. The first is the design of the paddles, and the next is the design of the actuation mechanism that produces parallel motion for effective gripping. The designed paddle is to grasp a wide variety objects with different shapes and sizes that are used in everyday life. The driving mechanism was designed with light-weight, effective, safe, self content and self-regulating of the robotic arm attached to it.

Marinus Maris [3] proposed a method for visual attention selection in mobile robots based on amplification of the selected stimulus. Attention processing is performed on the vision sensors which is integrated on a silicon chip and consists of a contrast sensitive retina with the ability to change the local inhibitory strength between adjacent pixel elements. The sensitivity to visual contrast at a particular region as a result the retina can be adjusted. As the local inhibitory strength can be regulated from outside of the chip, a reconfigurable sensor is realized. This ―attention-retina‖ was tested on an autonomous robot which was given the task of selecting a line to follow while there were two alternatives.

Y. Gene Liao [4]developeda straight-line pick and place motions are used for transferring work pieces into & out of an assembly or machine and are most advantageous in such application because of the accuracy of positioning the work pieces at the beginning and end of travel. The linear path or straight-line motion also exhibits great potential for reducing manufacturing cycle time. Healso describes the designand analysis of a robotic end-effectors that is capable of grasping objects of varying sizes and the center point of the end-effectors remains as close as possible to the same position, i.e. a straight line, over the range of pick and place movement. Selected shape and size of the grasped object ranges from 50 mm to 300 mm in cylindrical diameter. Preferred clamping force is 625 N per jaw when the gripper is at its maximum open position and a maximum lift mass is 70 Kg. The analyzed force applied on clamping, as the result the accuracy of motion trajectory, and stress of the end-effectors were analized.

CAD Modeling in FUSION360

Link Operatedgripper

The initial design of the link operated gripper is performed in Fusion360.The following figure depicts the initial CAD design of the link operated gripper.

Fig 1 Initial CAD model of Link operated gripper.

After constraining the dimensions and reducing the dimensions of the gripper to suit the requirements of the task, the above initial design of the gripper was deemed to be unfit for application. Hence, another CAD design was formulated taking the design constraints into considerations. The following figures depict the modifications made to the gripper to make it fit for application at a very smallscale.

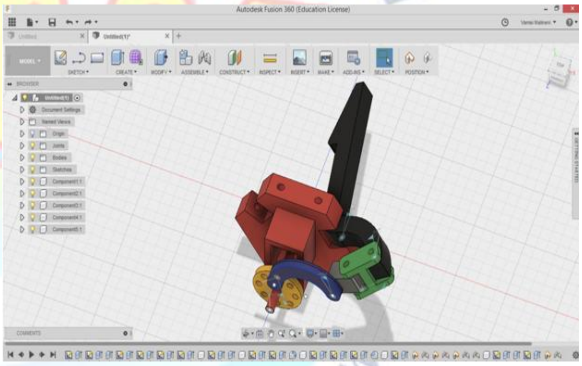


Fig 2: Sectional view of Link operated gripper with one finger

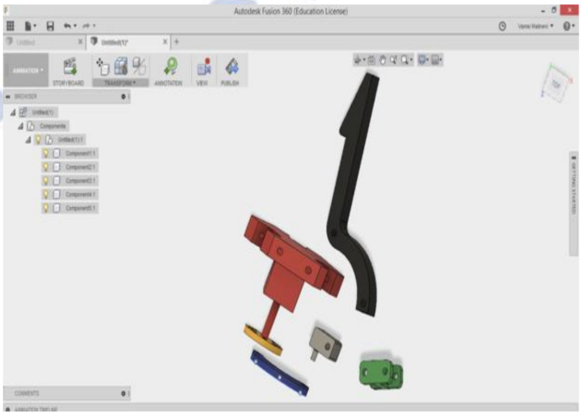


Fig 3: Exploded view of the link operated gripper

PROPOSED METHODOLOGY

Slicing and Cost Estimation

In general, many of the commercially available robotic end effectors do not accommodate extensive customization of the design features for attachment to different robotic arm platforms or integration of additional sensors for research and educational purposes [19]. Moreover, very high purchase and maintenance costs of the commercial robotic end effectors prevent their purchase by academic institutions, especially in developing countries. In this respect, the 3D printing rapid prototyping technology offers the way to produce low-cost robotic end effectors [12], [19], [20] that can be used in research and education [21]. This is facilitated by providing open-source computer-aided design (CAD) models of the end effectors that can be straightforwardly prototyped using a low-cost desktop 3D printer and assembled with off-the-shelf components. For instance, a 3D-printedopen-source tendon driven hand is proposed in [19] aiming to provide a basic robotic platform with minimal number of 3D-printed components and off-the-shelf actuator for facilitating robotic research efforts. In fact, open-source developmental methods already provide alternative to expensive and proprietary software packages, and gradually spread to other areas such as engineering research and education [3].To extend the choice of robotic end effectors freely available to researchers, in this paper the authors utilize a linkage based finger design and propose a low-cost open-source 3D-printed under actuated three-finger robotic gripper platform with a simple design and relatively higher payload property comparing to similar size tendon driven mechanisms [22]. The proposed design of the gripper platform can be easily customized and extended for use in various research and educational projects.

DESIGN OF A 3D-PRINTED THREE FINGER GRIPPER

As previously discussed, low cost is one of the principaldesign requirements for the developed robotic gripper. the fingers. For instance, changing the length of two actuation links of the finger can result in various dynamic outputs of the first and second phalanges. Selection of an appropriate spring stiffness coefficient K that defines actuation of the finger's second phalange is based on the kinematic analysis of the under actuated finger mechanism. The quasi-static equilibrium modeling of the finger is defined as follows. By equating the input and the output virtual powers [13], the following expression is

$$t^T \omega_a = f^T v \qquad (1)$$

Where t is the input torque vector, ω_a is the velocity vector, f is the vector of contact wrenches, and v is the vector containing the twist of the contact points.

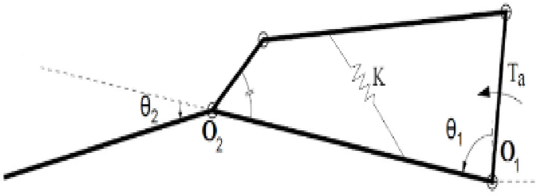
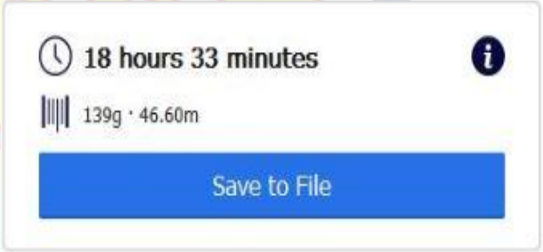


FIG 3: Schematic model of the 2-DOF under actuated finger

Cost Estimation:

Cost of gripper is less when compare to other manufacturing process or when compare to other 3d printing process I,e metal 3d printing, resin based printing process and ceramic based printing.


18 hours 33 minutes

139g · 46.60m

Total material consumption for gripper manufacturing is 139 grams

Total time for manufacturing the gripper is 18 hours 33 minutes

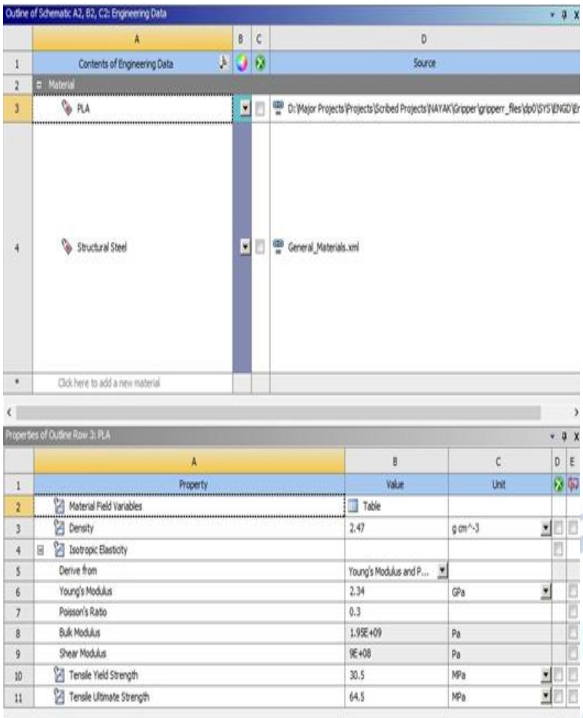
Based on per hour charge with PLA material is Rs 100/-

Per gram material consumption is Rs 6/-

The total cost is for printing the gripper is Rs 2684/-

FEM Analysis of Gripper

Analysis is performed on the base of the gripper where the total moment acts on the base part. Here we printed the base with PLA material. Similarly, structural analysis is performed for PLA material with maximum loading conditions.



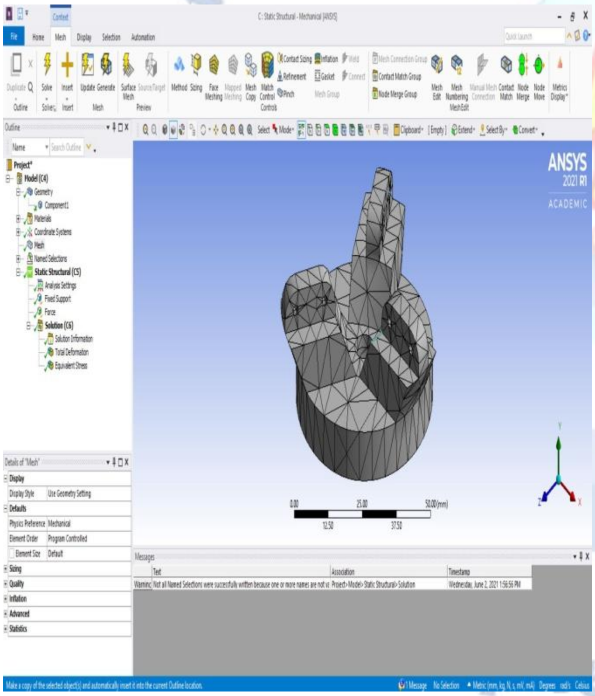
Outline of Schematic A2, B2, C2: Engineering Data

	A	B	C	D
1	Contents of Engineering Data			Source
2	⊟ Material			
3	PLA		☐	D:\Major Projects\Projects\Scribed Projects\NAYAK\Gripper\gripperr_files\dp0\SYS\ENGD\E
4	Structural Steel		☐	General_Materials.xml
*	Click here to add a new material			

Properties of Outline Row 3: PLA

	A	B	C	D	E
1	Property	Value	Unit		
2	Material Field Variables	Table			
3	Density	2.47	g cm^-3	☐	☐
4	⊟ Isotropic Elasticity			☐	
5	Derive from	Young's Modulus and P...			
6	Young's Modulus	2.34	GPa		☐
7	Poisson's Ratio	0.3			☐
8	Bulk Modulus	1.95E+09	Pa		☐
9	Shear Modulus	9E+08	Pa		☐
10	Tensile Yield Strength	30.5	MPa	☐	☐
11	Tensile Ultimate Strength	64.5	MPa	☐	☐

Fig 4: Creating PLA material in the ansys material library



Details of "Mesh"

⊟ Display	
Display Style	Use Geometry Setting
⊟ Defaults	
Physics Preference	Mechanical
Element Order	Program Controlled
☐ Element Size	Default
⊞ Sizing	
⊞ Quality	
⊞ Inflation	
⊞ Advanced	
⊞ Statistics	

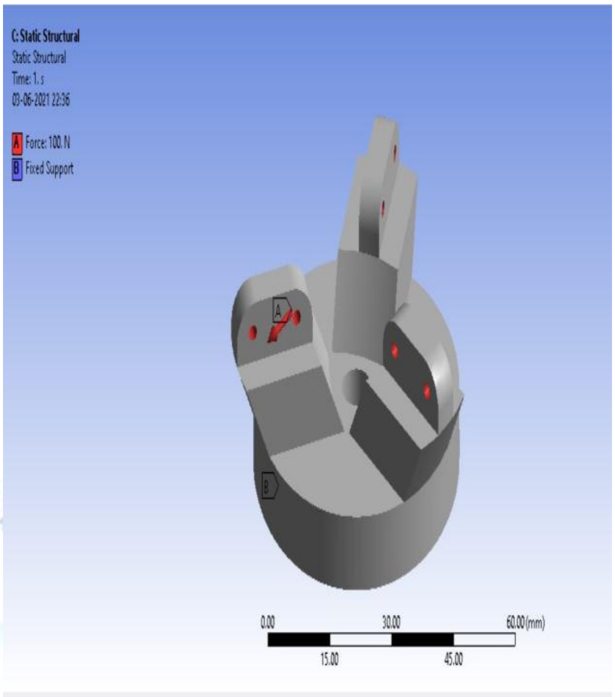
Messages

	Text	Association	Timestamp
Warning	Not all Named Selections were successfully written because one or more names are not v	Project>Model>Static Structural>Solution	Wednesday, June 2, 2021 1:56:56 PM

Make a copy of the selected object(s) and automatically insert it into the current Outline location.

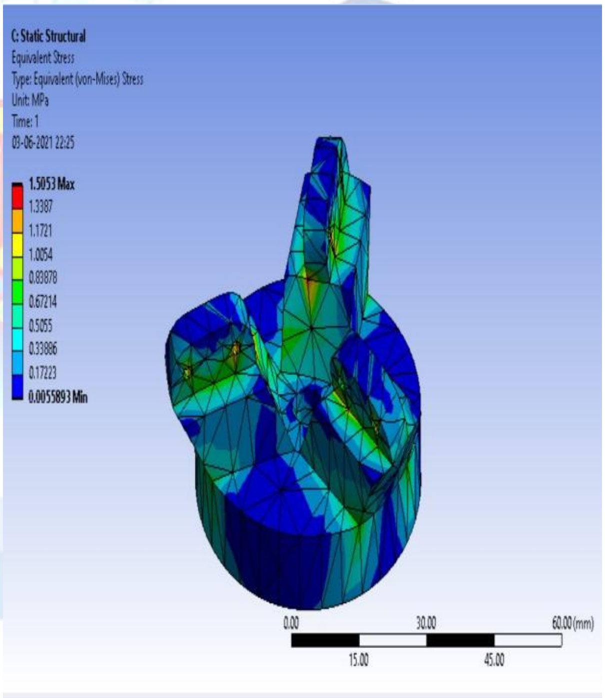
1 Message No Selection Metric (mm, kg, N, s, mV, mA) Degrees rad/s Celsius

Fig 5: Meshing View of The Gripper Base



C: Static Structural
Static Structural
Time: 1. s
03-06-2021 22:36

Fig 6: Applying Boundary Conditions



C: Static Structural
Equivalent Stress
Type: Equivalent (von-Mises) Stress
Unit: MPa
Time: 1
03-06-2021 22:25

Fig 7: Stress Distribution in Gripper Base

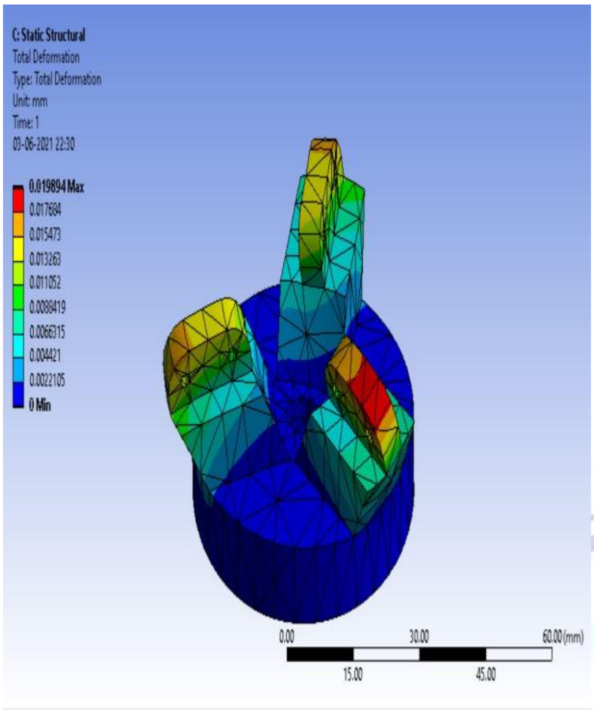


Fig 8: Deformation Distribution in Gripper Base

NUMERICAL RESULTS

Gripper Designcalculations

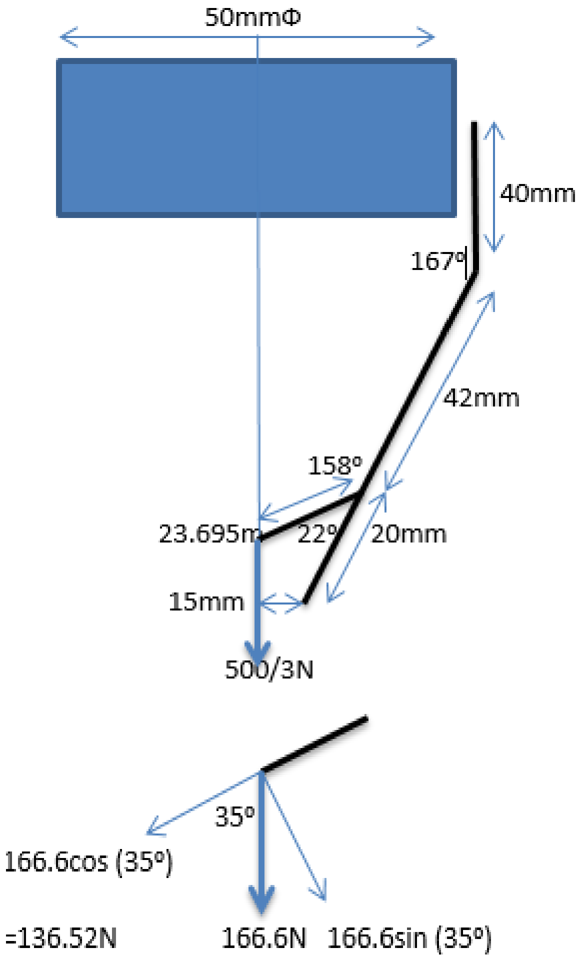
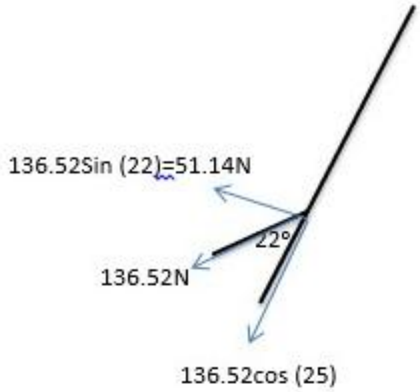
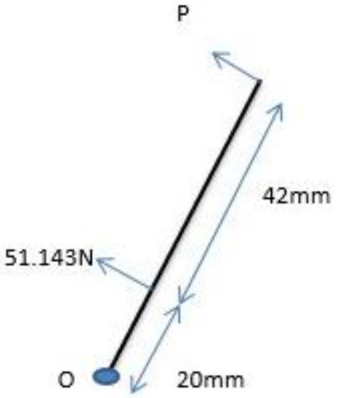


Fig 9: Force Distributions.

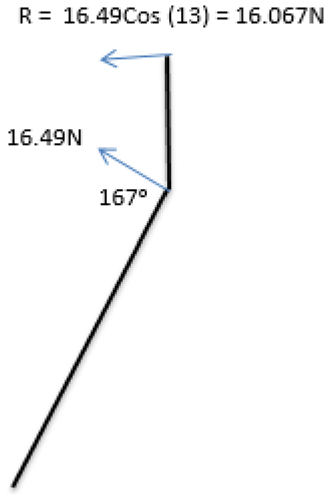




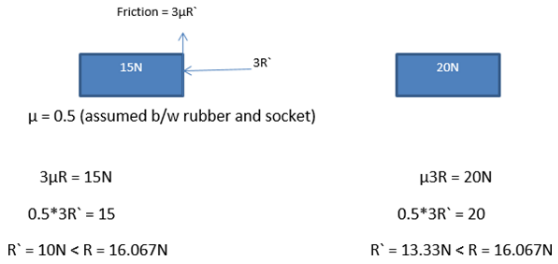
Moments about 'O'

P * (20 + 42) = 51.143 * 20

P = 16.49N



The resultant output force = 16.067N



$3\mu R = 15N$

$0.5*3R` = 15$

$R` = 10N < R = 16.067N$

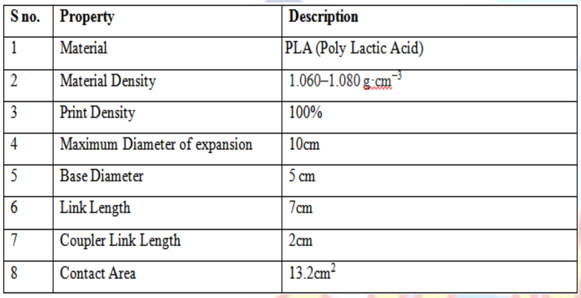
$\mu 3R = 20N$

$0.5*3R` = 20$

$R` = 13.33N < R = 16.067N$

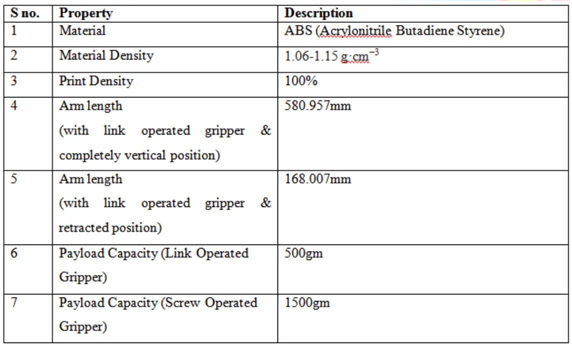
Selection of material:

- Excellent impact, chemical and abrasion resistance.
- Superior stiffness and strength.
- Easily machined and thermoformed.
- Easy to paint and glue.
- Good dimensional stability.
- Excellent electrical properties.



S no.	Property	Description
1	Material	PLA (Poly Lactic Acid)
2	Material Density	1.060–1.080 g·cm^{-3}
3	Print Density	100%
4	Maximum Diameter of expansion	10cm
5	Base Diameter	5 cm
6	Link Length	7cm
7	Coupler Link Length	2cm
8	Contact Area	13.2cm^2

Table 1: Gripper Specifications



S no.	Property	Description
1	Material	ABS (Acrylonitrile Butadiene Styrene)
2	Material Density	1.06-1.15 g·cm^{-3}
3	Print Density	100%
4	Arm length (with link operated gripper & completely vertical position)	580.957mm
5	Arm length (with link operated gripper & retracted position)	168.007mm
6	Payload Capacity (Link Operated Gripper)	500gm
7	Payload Capacity (Screw Operated Gripper)	1500gm

Table 2: Arm Specifications

Cost Estimation:

The total cost of the printing process is Rs 2684/- which is very less when compare to other manufacturing process. Printing time also reduces when compare to other manufacturing process.

Analysis Results:

PLA material is giving better results for maximum loading conditions. The induced stress when the maximum loading is applied is 1.505395 MPa when compare to PLA material Yield strength is very less and the maximum deformation, we found is 0.019894 mm. which indicates the gripper is in safe condition.

CONCLUSION

The Snake like Robotic Arm was initially designed to carry a payload of 1.5Kg and was required to maneuver through various obstacles without damaging the scenario. In this regard we have developed and designed three grippers to analyze their capability to achieve the given problem statement.

After consequent trials and rapid prototyping the grippers, the gear operated gripper couldn't be rapid prototyped owing to the fact that the precision required for indexing of gears couldn't be achieved. The gears used in the gripper were too small to be 3d printed with high accuracy and precision.

The Link operated and Screw operated grippers were 3D printed from the JULIA+ Desktop 3D printer. The link operated gripper was attached to a micro servo of 1.2Kg- cm torque owing to the major design constraints; this resulted in the low payload carrying capability.

The Screw operated gripper was 3D printed using ABS Plastic as the base material having a thickness of 1.060-1.080 g cm^{-3}, and the print density being 100%. The Screw operated gripper was 3D printed for the carrying of a maximum payload of1.5Kg.

The material properties used in the manufacture of the arm and the gripper is mentioned in the table 2.

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