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DEVELOPMENT OF ELECTRONIC -TYPE FINGER FORCE MEASURING SYSTEM AND EVALUATION OF ITS CHARACTERISTICS ON INVESTIGATED PNEUMATICALLY ACTUATED TWO FINGERED ENCOMPASSING GRIPPER

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ABSTRACT

- The Purpose of our work is to develop a sensor for realize the amount of required force during grasping in gripping mechanism, and testing it on investigated pneumatically actuated two fingered encompassing gripper.
- **Material and Method:** In this paper an experimental system has been proposed for a force control of a two finger pneumatic encompassing gripper with an economy, easy sensitizing by using digital force sensor. This sensor has been used for finding the required amount of grasping force (N) for holding different coefficient of friction grasping objects in minimum working pressures (Bars) with respect to maximum holding weight without slippage. And also theoretical calculations were done for checking and proving the accuracy of this type of force sensor.
- The results show a good agreement between theoretical and experimental results, therefore the developed force sensor is sufficient enough to be used as a force sensor for determining the amount of force needed by the gripper to grasp the unknown object.

KEYWORDS: Pneumatic Encompassing Gripper Design, Electronic Force Sensor, Gripping Force

INTRODUCTION

There are different mechanical grippers which are based on different motor technologies have been designed and employed in numerous applications. The handling of abstract materials and mechanisms for picking and placing are widely found in factory automation and industrial manufacturing. Kim (2004) [1] described the small 6-axis force/moment sensor for measuring forces Fx , Fy and Fz, and moments Mx, My and Mz, and simultaneously was modeled using several parallel-plate beams (PPBs), designed and fabricated. A characteristic test of the made sensor was performed, and the result showed that the interference errors of the developed sensor were less than 3.93% and this represent the forces, moments in the grasping and the gravity directions.

Daroogheha and Radhakrishnan(2007)[2] focused on their study on the development of a suitable linkage mechanism for compact and lightweight gripper using two different actuation methods. The first design investigates the use of shape memory alloy springs(SMA), and the second design was developed using a more conventional, servomotor-based actuation. Additionally, an accurate analysis involving the gripper mechanism’s tolerances and clearances was developed for both grippers. The study showed that both grippers hold promise for certain applications and should be considered in the design of mini mobile robot devices**.**

Takaki and Omata(2011)[3] presented a lightweight anthropomorphic robot hand that can exert a large grasping force. They proposed a mechanism combining flexion drives and a force-magnification drive for a cable-driven multi-fingered robot hand. The flexion drive consisted of a feed screw which enables a quick finger motion. The force-magnification drive consisted of an eccentric cam, a bearing, and a pulley, to enables a firm grasp. They also proposed a 3-D linkage for the thumb, which was consists of four links and was driven by a feed screw, it can oppose to a large force exerted by the force-magnification drive. They experimentally verified that the maximum fingertip force of the hand exceeds 20 N and that the thumb can hold a large force of 100 N. The time to fully close the hand using the flexion drives was 0.47 second. But after the fingers make contact with an object, the time to achieve a firm grasp using the grasp-magnification drive was approximately 1 second. Carbone and González (2011) [4] described the development of a grasping model for LARM Hand IV, which was a robotic hand having three 1-DOF anthropomorphic fingers. A control algorithm have been tested for regulating the grasp force that was provided by each finger in order to achieve a suitable firm grasp even in dynamic conditions.

Shirafuji and Hosoda (2012)(5) developed an anthropomorphic human scale robot hand equipped with an elastic skin in which two types of sensor were randomly embedded. One of these sensors was a piezoelectric film which can be used for the detection of pressure changes, while the other was a strain gauge which can measure static pressure. They show that this system can control the grasp force of the robot hand and adapt it to the weight of the object. But Kim *et al* (2012) [6] developed two cylindrical-type finger force measuring systems with four force sensors for left and right hand fingers. The developed finger force measuring system can measure the grasping force of each patient's finger and the measured results could be used to judge the rehabilitation extent of each finger. The grasping force tests of men and women were performed using the developed cylindrical-type finger force measuring systems. The tests confirm that the average finger forces of the right and left hands for men were about 194 N and 179 N, and for women were 108 N and 95 N.

Yaqub and Atif(2012) [7] designed and developed a tele-operated robotic hand system which was intended for providing solutions to industrial problems like robot reprogramming, industrial automation and safety of the workers working in hostile environments. The robotic hand system works in the master slave configuration where the Bluetooth was used as the communication channel for the tele-operation. The results showed that the successful establishment of communication between master and slave at a rate of 10 packets per second, which was sufficient for smooth motion of the system.

Her *et al* (2013) [8] modularized anthropomorphic robotic hand that requires fewer actuators to control its total degrees of freedom. Two types of fingers were derived from a single kinematic inversion of the Watt six-bar chain, each then transformed into a seven-bar mechanism by adding a pivoting ground link. Both finger mechanisms were operated with a tendon drive system. Using two more links in the design of the robotic fingers enables better imitation of the motion and grasping an object. Langde and Jaju(2013) [9] provide a review to cover methodologies in compound gripper, multifunctional gripping technologies, and concentric gripping. They also made innovations in gripping techniques and suggests improvements using innovative changes in existing grippers.

A gripper is an end-of-arm tooling used on robots for grasping, holding, lifting, moving and controlling of materials whenever they are not processed. For repetitive cycles, heavy loads and under extreme environments, grippers had to be developed to substitute for human hands. In the 1960s, after the emergence of modern robots, grippers replaced human hands on numerous occasions. Robot-gripper systems are found to be effective for repetitive material handling functions in spite of their initial capital and ongoing maintenance expenses because of their reliability, endurance and productivity. For manufacturing systems where flexibility is desired, the cost of a suitable gripper may even go higher since they require additional controls, sensors and design needs with regards to being able to handle different parts [10].

Pham and Tacgin (1992) [11] built a hybrid expert system that employs both rule-based and object-oriented programming approaches. Typically, gripper mechanisms and major features are defined by their driving forces. The driving forces for robot grippers are usually electric, pneumatic, hydraulic; or in some cases, vacuum, magneto-rheological fluid and shape memory, etc. Grippers with electric motors have been used since 1960 and many other grippers adopted motor driven mechanisms. Basically, this type of systems included step motors, ball screws, encoders, sensors and controllers. As the arms approach the object, distance, force, weight and slip are detected by sensors. At the same time, a controller regulates the force, speed, position and motion. Friedrich *et al* (2000) (12) developed sensory gripping system for variable products and used multiple sensors to measure the grasping force, weight and slip. Lee and Nicholls (1999) [13] comprehensively reviewed the field of tactile sensing for contact and slip. Tremblay and Cutkosky (1993) [14] considered slip detection, but Howleg *et al* (1996) [15] divided slip into four stages; pre-slip tension, slip-start, post-movement and stop, to better analyze grasping of parts.

Another way of actuating the robot gripper is through pneumatic (or hydraulic) systems. Pneumatic systems have been developed because of their simplicity, cleanliness and cost-effectiveness. Ottaviano *et al* (2000)[16] developed grasp-force control in two-finger grippers with pneumatic actuation. They proposed force control in a two-finger gripper with a sensing system using commercial force sensors. A suitable model of the control scheme has been designed to control the grasping force. Experiments showed the practical feasibility of two-finger grippers with force controlled pneumatic actuation.

Qassab et al (2013)[17] investigate a new design and prototyping method for pneumatically actuated hand of robot, consisted of two curved fingers using several plate beams made from low carbon steel. The design was based on static analysis using non-linear finite element method; derived equations for stress and deformation of the hand; and, found the maximum holding weight of designed hand. Nazural et al (2013)[18] discussed smoothing the grasping force analysis and optimization of the three fingertips grasp by using Gaussian filtering method(computational Gaussian algorithm) in which developed in their previous work called GloveMAP. It was designed to reduce the overshoot signal and suitable to be used for filtering grasping force input signal while minimizing the rise and fall time of the grasping object.

In order to achieve a level of precision gripping just like humans hand, the present research was aimed to design and work on highly versatile, multi fingered robotic hands that offered a multiple degrees of freedom, and achieved grasping with two fingered robot grip in respect to the applied pressure and the holding weight, and to found the amount of force applied by using digital weight sensor fixed on the hand. Double acting pneumatic cylinder was used to perform a grasping process on different work pieces depending on their weight and coefficient of friction.

MATERIALS AND METHODS

A. Analysis and Fabrication of a Flexible Gripper: In order to complement the efforts and realize the full benefits of reconfigurable and flexible manufacturing systems, the designed prototype of a flexible gripper system was based on pneumatically actuated piston ring which was connected to a slider Figure 1; then the fingers were jointed to the two flexible linkages.

Figure 2 shows kinematic scheme of the gripping mechanism. The crank slider mechanism (DEG) represents the gripping system of the hand prototype; the piston is the actuation component; the coupler (CQ) is the finger link; and (L) is the crank length of the hand; the length of the crank and coupler are denoted by (b) and (c); (r) is the minimum distance between the point D and the piston axis. The angle β between links DC and DE is constant and it is right angle (90˚).

In this mechanism the linear motion of a piston rod was converted to the circular motion of the fingers. The actuator was able to give the prescribed maximum force of (152.6N) under working pressure of (6 Bars). The amount of force exerted during grasping was measured by a commercial weight sensor.

B. Weight Sensor Description: The model Electronic kitchen weight sensor SF_400 (china) as seen in Figure 3, consists from the load cell Figure 4 which is a transducer that is used to convert a force into an electrical signal. This conversion is indirect and happens through a mechanical arrangement, the force being sensed deforms a strain gauge. The strain gauge measures the deformation (strain) as an electrical signal, because the strain changes the effective electrical resistance of the wire. The electrical signal output is typically in the order of a few volts and requires amplification by an instrumentation amplifier before it can be used. The output of the transducer can be scaled to calculate the force applied to the transducer. Figure 5 shows the weight sensor circuit diagram.

C. Experimental Background and Tests: After the gripper mechanism has been settled up and tested with the gripping mechanism shown in Figure 6, it has been possible to measure the grasp forces in different working pressures for several kinds of samples in the way that each load cell could read the amount of load that exactly acts on the finger. During the experiment three types of samples were used (rubber, solid metal and plastic bottle filled of water), and for each of them different values of weight was tested to be hold by the hand with the minimum working pressure without the slippage. Table 1 shows the data that obtained during the experimental work; As an initial point of view, the experimental results shows that by increasing the grasping weight the amount of grasping force was increased; this led to increasing actuating force by increasing the working pressure.

During grasping a bottle of water; because of the lower friction coefficient between the surfaces of the gripper fingers and the surface of the bottle; the amount of working pressure was doubled for grasping the same amount of other grasped object.

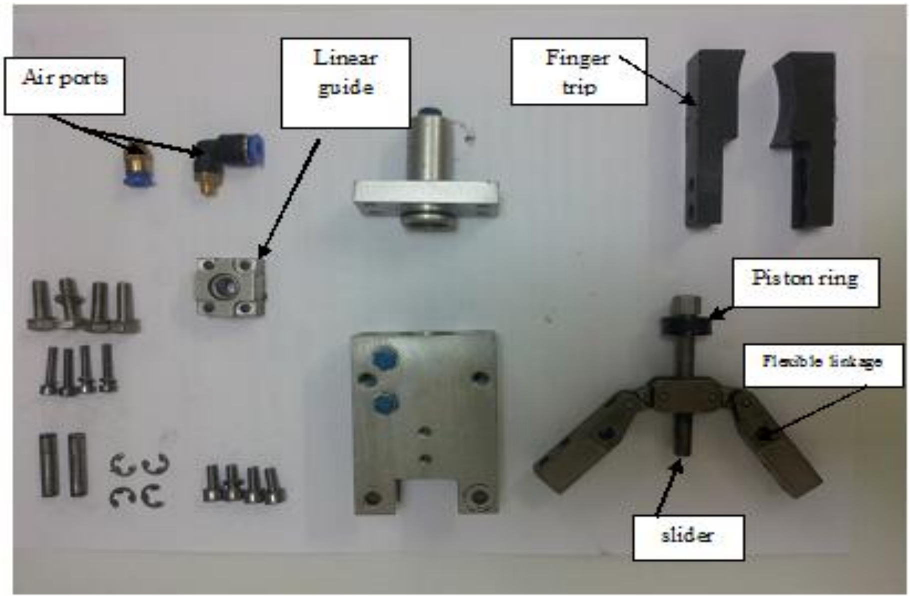


Figure 1: The Detailed Sketch of the Parts of Gripper. Specifications of the Gripper: Piston Diameter (15mm), Piston Rod Diameter (5mm), Length of Stroke (20mm) Material: Carbon Steel

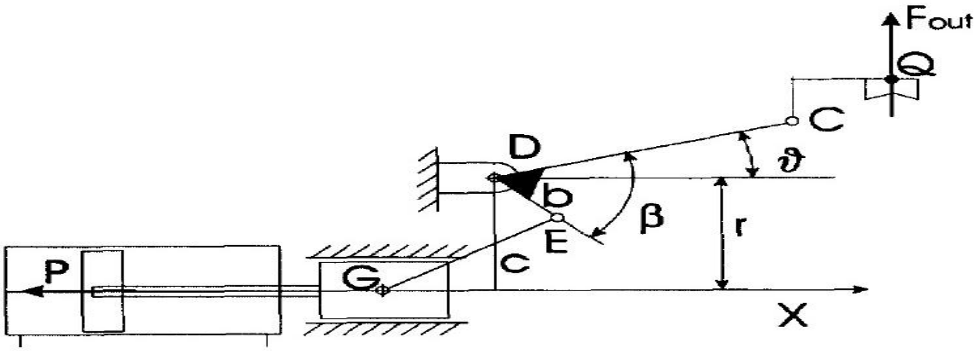


Figure 2: Kinematic Scheme of the Gripping Mechanism

Figure 3: The Model Kitchen Weight Sensor Used in the Study

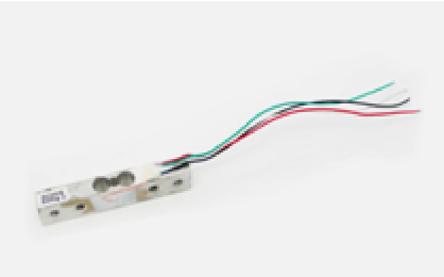


Figure 4: Load Cell, a Transducer that is Used to Convert a Force into an Electrical Signal

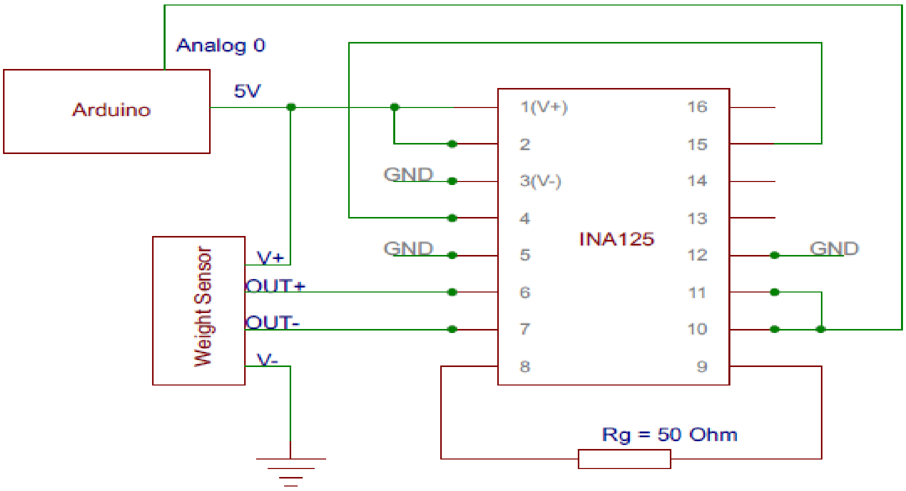


Figure 5: Weight Sensor Circuit Diagram

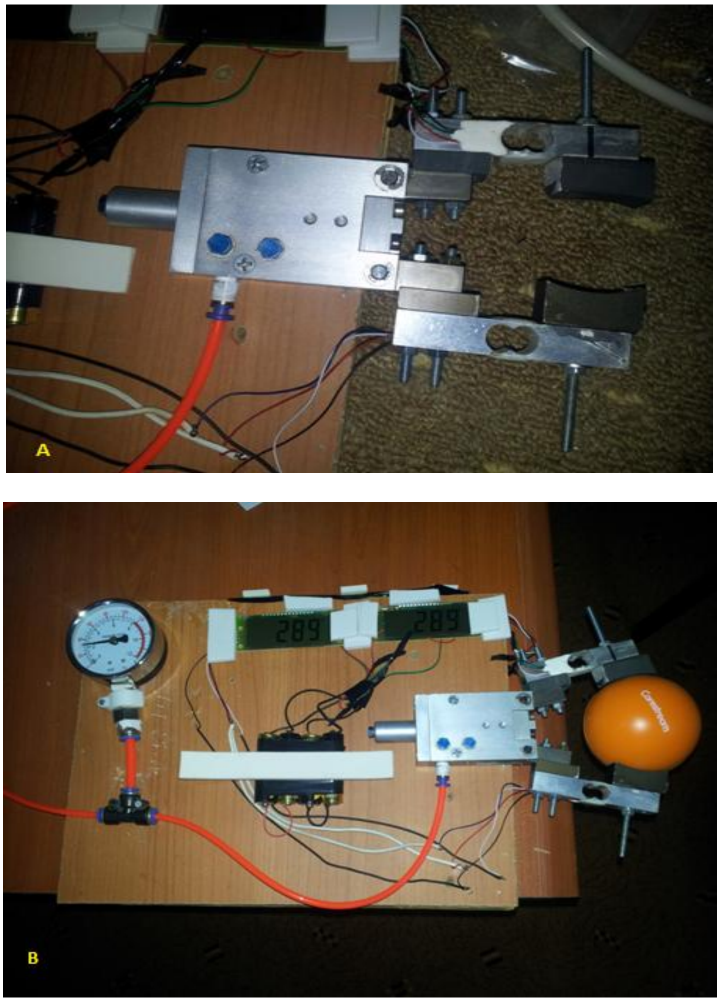


Figure 6: The Gripper Mechanism has been Settled up (A) and Tested (B)

Table 1: The Data that Obtained during the Experimental Work

Material	No	Working Pressure (Bar)	Weight of the Sample (Gram)	Force Sensor Reading(g)
Rubber	1	0.2	4	29
	2	0.5	10	78
Solid metal (Carbone Steel)	3	0.5	24	80
	4	1	54	175
	5	1	104	212
	6	1.5	154	235
	7	1.6	204	275
	8	2.5	254	450
	9	2.5	304	524
	10	2.5	354	530
	11	2.6	404	540
	12	3.5	454	720
	13	4	504	900
	14	7	604	1000
Plastic bottle filled with water	15	3.5	100	617
	16	4	200	725
	17	5	300	960
	18	5.5	400	990
	19	6	500	1125

RESULTS AND DISCUSSIONS

The study focused on calculating the gripping force and the sliding torque on the investigated gripper. The encompassed grip was preferred on friction grip because it requires one fourth the forces required for holding the same object, and it provide more strength and stability Figure 7. The calculations regarding the gripping force for the gripper have been achieved through the equation presented below [23]:

$$F_G = \frac{m(g+a)}{2\mu} \sin \beta . s$$

Where F_G = Gripping force (N)

m: Mass (gram)

g: Gravitational acceleration (m/sec^{2})

a: Gripper acceleration (In our case a=0, because the gripper is fixed)

µ: Frictional coefficient

β: Angle between jaws of the gripper= 90°

s: Safety factor(always greater than 1 for design purposes, but in this case =1 for case of comparison only)

µ[19]= 0.3 (finger surface: aluminum, work piece surface: steel)

=0.2 (finger surface: steel, work piece surface: plastic)

=0.075 (finger surface: steel, work piece surface: Rubber)

The calculated gripping force for each of the cases used in the study were found theoretically and compared with the results obtained experimentally by using the commercial force sensors as seen in Figure 8. The obtained amount of force experimentally was near to the values obtained theoretically in the case of grasping an object made from carbon steel in comparison with other materials; that is because when the gripping force acted on the strip of the load cell it stressed within the elastic limit of the metal strip so that the strip did not permanently deform and this led to inaccuracy data, unlike a case of gripping the carbon steel work pieces.

CONCLUSIONS

The obtained results showed that the kitchen weight balance sensor can be used as a force sensor in an intelligent robot’s fingers for stable grasping of an object. The newly modeled force sensor has the maximum error of about to 12% and the developed force sensor is sufficient enough to be used as a force sensor for determining the amount of force needed by the fingers of the gripper to grasp the unknown object.

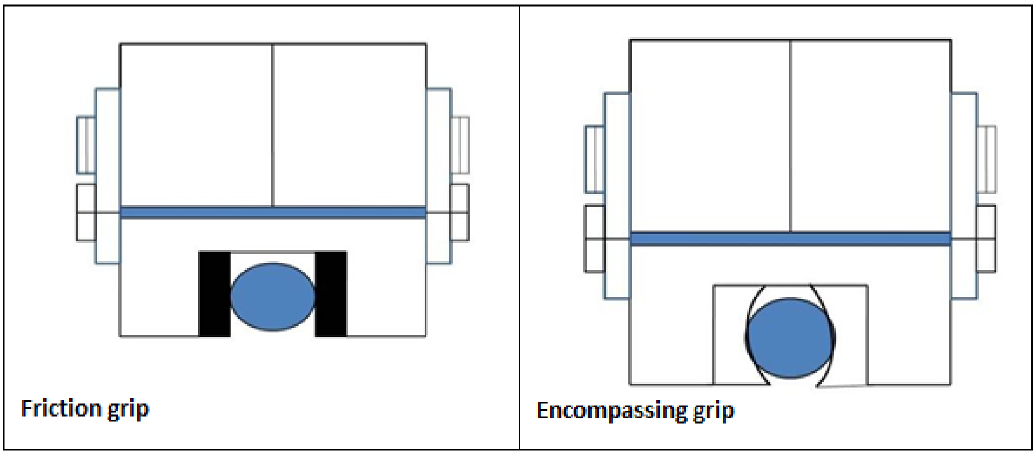
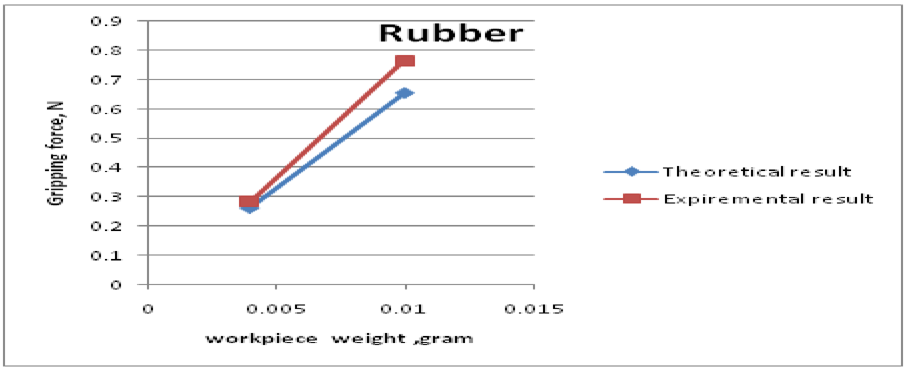
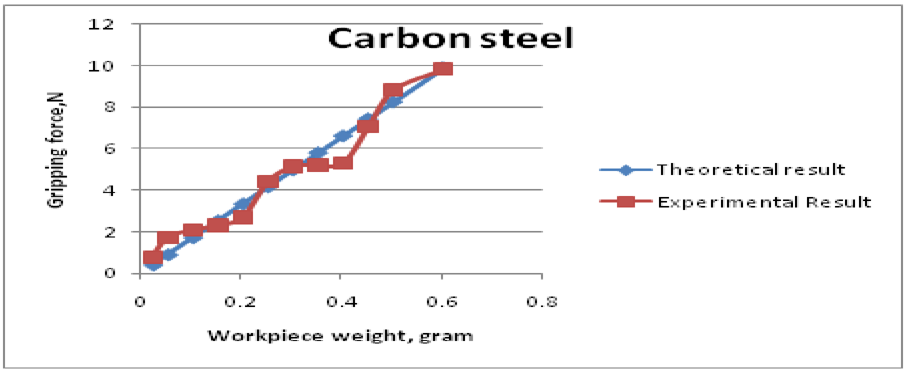


Figure 7: Encompassing Grip during Grasping Provide More Strength and Stability





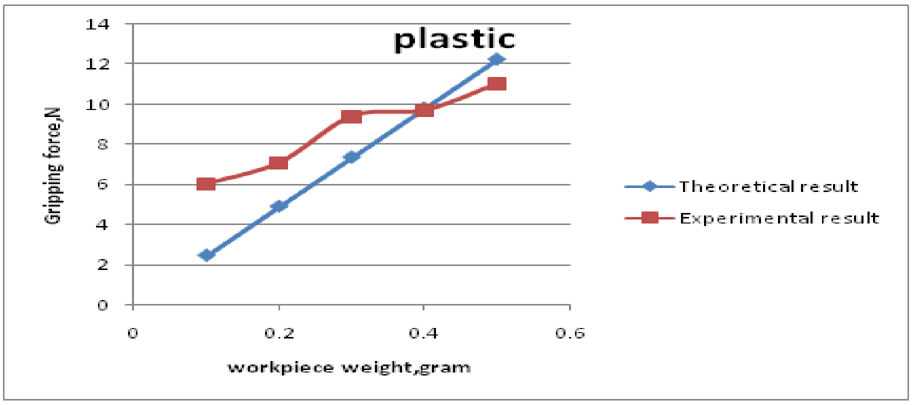


Figure 8: Shows the Comparison between Theoretical and Experimental Results for Each of Three Cases (Rubber, Carbon Steel, Plastic Bottle Filled with Water)

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