STROKE ENHANCEMENT ADAPTER FOR ELECTRIC PARALLEL GRIPPER EQUIPPING A MOBILE X-Y-Z ROBOTIC SYSTEM

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Abstract: *The general purpose is to build a mobile robotic system, carrying a x-y-z robotic manipulator equipped with an electric parallel gripper. The gripper is intended to collect waste objects from the ground and to manipulate them to a box container placed on the mobile robot. Unfortunately, grippers with both long stroke and sufficient gripping force are much too heavy. In fact, the admissible load for the x-y-z robotic manipulator carrying the gripper is quite limited, due to its actuation using only 24 VDC. The simple and reliable electric parallel gripper EHPS-25 provided by FESTO, has the following technical characteristics: total stroke 32 mm, gripping force 125 N, gripper mass 0.9 kg. To meet the technical requirements of larger stroke, we propose a stroke enhancement adapter, actuated by the electric parallel gripper at one side by 125 N for a total stroke of 32 mm, and providing to its other side 50 N for an increased stroke of 80 mm.*
Keywords: *electric parallel gripper, mobile robotic system, stroke enhancement adapter, gripper stroke, gripping force*

1. INTRODUCTION TO ELECTRIC PARALLEL GRIPPERS

In the framework of national PCCDI project entitled “Autonomous robot systems for waste management in the context of smart city” (acronym SIRAMAND), contract no. 22 PCCDI /2018, the idea is to build a mobile robotic system, carrying a *x-y-z* robotic manipulator equipped with an electric parallel gripper. The gripper is intended to collect waste objects from the ground and to manipulate them to a box container placed on the mobile robot. Figure 1 shows the overall scheme of SIRAMAND mobile robotic system, the gripper being the end-effector tool responsible for grasping various waste objects. Being a mobile robotic system, the overall actuation must be performed using only 24 VDC. Due to this voltage limitation, the admissible load for the *x-y-z* robotic manipulator carrying the gripper is quite limited, moreover the gripper must eventually be connected to a rotary-swivel unit. Thus, the gripper must be electric, not too heavy, but providing enough stroke and gripping force for grasping as much waste objects as possible. The technical specifications for such an electric parallel gripper are as follows: total stroke (both sides) 60÷120 mm, gripping force 50÷100 N, gripper mass < 1 kg.

Figure 1: Overall scheme of SIRAMAND mobile robotic system

In what concerns the electric gripper, there are two variants: using an industrial gripper adapted to SIRAMAND project needs, or building an in-house gripper.

In fact, numerous research teams have proposed various electric in-house grippers. For example, Barbieri et al. [1] proposed an underwater robotic arm equipped with an adaptive gripper realized using additive manufacturing technologies. This gripper is presented in Figure 1a (taken from [1]), being equipped with two adaptive fingers in order to be able to grasp objects of various shapes. The adaptive gripper is able to rotate around the robotic arm wrist, while the fingers are moved by a self-locking mechanism in which an endless screw is driven by an actuator, sending motion to the fingers by means of two pairs of gears. The fingers have an anthropomorphic kinematic structure, being composed of two phalanges (equivalent of human proximal phalanx and intermediate phalanx), allowing two degrees-of-freedom using only one actuation. Due to the special parallel structure of the first/proximal phalanx, which incorporates a helical elastic spring, the adaptive finger gripping mechanism is simple and natural: when the proximal phalanx comes in contact with the grasped object, its rotation is blocked, but the actuation enables still the rotative closure of the second/intermediate phalanx (until it comes also in contact with the object). Moreover, the intermediate phalanx is continued with a distal phalanx having the form of a FinRay pattern structure, patented by FESTO. The current FESTO product based on this FinRay pattern structure are the adaptive gripper fingers DHAS [2].

Another versatile in-house gripper is the combined gripper proposed by Bonello et al. [3], mounting in parallel a 2-finger mechanical gripper and a vacuum cup, respectively. The vacuum cup is located at mid-distance between the two fingers jaws, being attached to a freely retractable tube member which is normally in the fully extended position due to gravity. This versatile gripper, combining classical grasping using friction with the supplementary vacuum aspiration, is able to successfully grasp objects of different shapes, sizes and weights [3].

Let us cite also a third in-house interesting gripper, equipping the mobile robot Cosero, proposed by Stückler et al. [4]. Cosero is a mobile robot with two anthropomorphic arms, mounted on a trunk that can slide on a vertical guide. The anthropomorphic arms are equipped with parallel grippers, actuating by rotary joints two FESTO FinRay fingers [2]. When this gripper grasps an object by closing its two fingers, this flexible FinRay bionic finger structure has the property of adapting to the shape of the object, thus significantly increasing the contact surface between the fingers and the object (compared to a rigid mechanical structure). Moreover, the FinRay adaptive fingers surface was covered with anti-skidding material, in order to increase the frictional force with the object and thus the gripping.

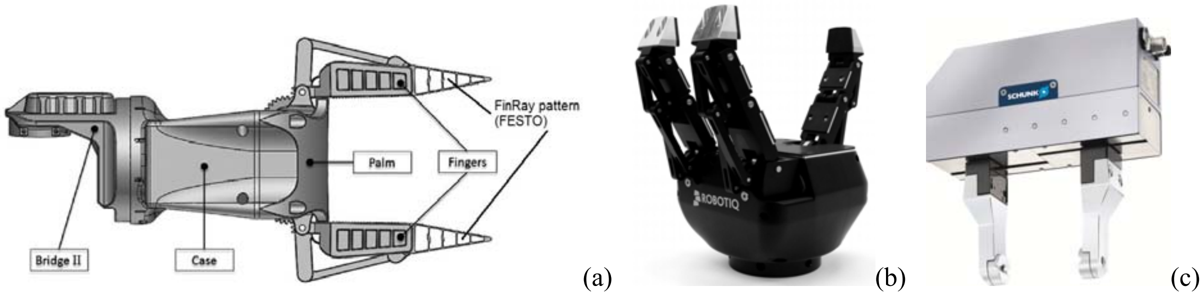


Figure 2: Various electric grippers: (a) in-house adaptive gripper proposed by Barbieri et al. [1]; (b) industrial 3-Finger Adaptive Robot Gripper produced by ROBOTIQ [5]; (c) industrial 2-finger parallel gripper WSG 050-110-B produced by SCHUNK [6]

Concerning industrial grippers, the market offers a multitude of variants, with more or less similar technical performance. An interesting grasping solution is using a 3-finger gripper, such as the 3-Finger Adaptive Robot Gripper produced by ROBOTIQ showed in Figure 2b [5], with the following technical data: gripper opening 0÷155 mm, gripping force 15÷60 N, gripper weight 2.3 kg. Unfortunately, this ROBOTIQ 3-Finger Adaptive Gripper is much too heavy for our mobile robotic system application. In general, grippers with both long stroke and sufficient gripping force are much too heavy.

The most used industrial grasping solution for small parts/objects is the 2-finger parallel gripper, illustrated in Figure 2c by the WSG 050-110-B gripper produced by SCHUNK [6]. This SCHUNK WSG 050-110-B gripper is defined by the following technical data: total stroke (both jaws) 110 mm, gripping force 5÷80 N, gripper weight 1.2 kg (this gripper is a little bit too heavy), recommended workpiece weight 0.4 kg.

Usually, the gripping force should be from 10 to 20 times the workpiece weight. In fact, for grippers where grasping involves the friction between the finger jaws and the workpiece/object, the workpiece weight that can be actually manipulated depends on the friction coefficient between the gripper fingers and the workpiece, as well as on the shape of the workpiece. For a 2-finger parallel symmetric gripper, the gripping force and the workpiece/object weight are related by the following expression:

$$F_{\text{grip}} = \frac{mg}{2\mu} S \qquad (1)$$

where F_{grip} is the gripping force, m the workpiece/object mass, g = 9.8 m/s^2 the gravitational acceleration, μ the static friction coefficient between gripper jaws and object (usually in the range between 0.1 and 0.3) and S=2÷4 the margin/safety coefficient. So, as a rough guide, depending on the value of μ and on the S margin value considered, a workpiece's weight should not exceed 1/10 to 1/20 of the gripping force. The use of anti-skidding material to cover the finger jaws is meant to increase the friction coefficient μ and thus to be able to manipulate heavier objects/workpieces for the same gripping force.

2. FESTO ELECTRIC PARALLEL GRIPPER EHPS-25

A gripper that is able to fit the technical specifications of our project is the electric parallel gripper EHPS-25 provided by FESTO [7]. Figure 3a shows a general view of this EHPS-25 gripper, while Figure 3b shows the vertical mounting position of the original gripper jaws, with lengths of 45, 65 or 95 mm [7].

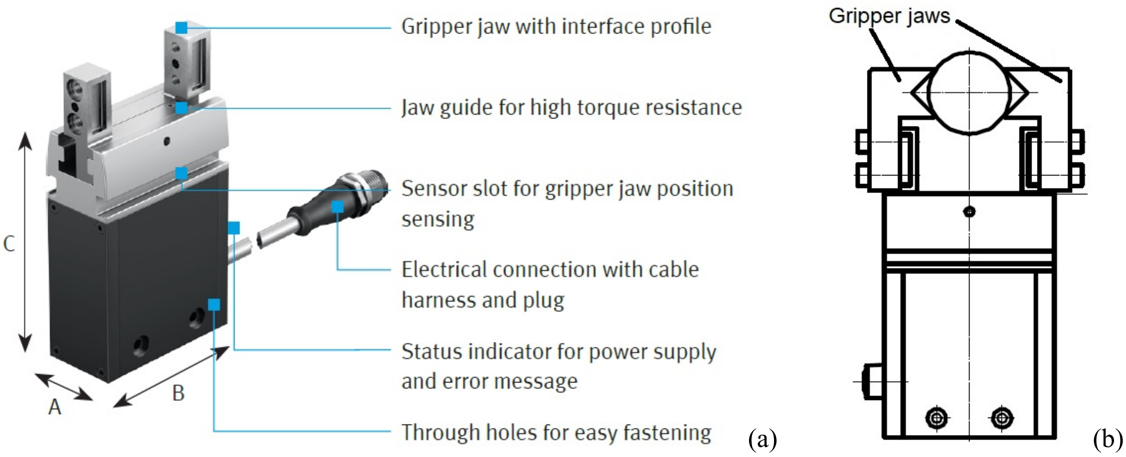


Figure 3: FESTO electric parallel gripper EHPS-25: (a) general view with indication of component parts [7]; (b) vertical mounting position of the gripper jaws [7]

The technical data of EHPS-25 electric parallel gripper are as follows:

- total stroke (both jaws) 32 mm; gripping force 125 N; closing time 0.44 s;
- gripper weight 0.9 kg; materials: aluminium (housing, cover); ambient temperature −5÷60 °C;
- gripper finger data: permissible gripper finger length 120 mm, maximum mass per finger 230 g.

The admissible load for the *x-y-z* robotic manipulator carrying the gripper is quite limited, due to its actuation using only 24 VDC. This EHPS-25 gripper has an acceptable weight, meeting the technical specification "gripper mass < 1kg".

To meet the other technical requirements: "total stroke (both sides) 60÷120 mm, gripping force 50÷100 N". this gripper must increase its total stroke until at least 60 mm, but has the possibility to decrease its gripping force until 50 N. For this purpose, we propose an innovative stroke enhancement adapter, inspired from the operating mechanism of scissors.

3. INNOVATIVE STROKE ENHANCEMENT ADAPTER

In order to increase the total stroke of FESTO electric parallel gripper EHPS-25, by decreasing the gripping force, an innovative stroke enhancement adapter is proposed, inspired from the operating mechanism of scissors. Figure 4a shows a perspective view of this new stroke enhancement adapter.

The scissors and thus our stroke enhancement adapter, obey to the mechanical momentum conservation principle, transposed in our case as follows (see Figure 4c for illustration of dimensions and forces involved):

$$F_{1,\text{gripper}} l_1 \cos\alpha = F_{2,\text{grasp}} l_2 \cos\alpha \quad (2)$$

where $F_{1,\text{gripper}} = 125$ N is the gripping force provided by the EHPS-25 gripper, being parallel with the grasping force $F_{2,\text{grasp}}$ provided at the other end of the stroke enhancement adapter, where the object is grasped. The angle α is half of the opening angle of the "scissor", while l_1 and l_2 are the small and the big arm of the "scissor", respectively, linked by the following geometrical relation:

$$\frac{l_1}{l_2} = \frac{s_{1,\text{gripper}}}{s_{2,\text{grasp}}} \quad (3)$$

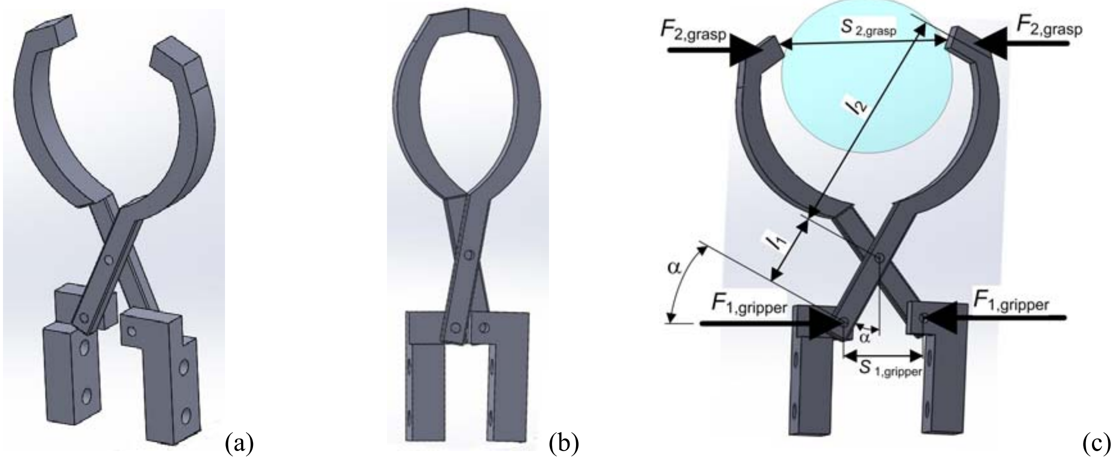
with $s_{1,\text{gripper}} = 32$ mm the gripper stroke and $s_{2,\text{grasp}}$ the new grasp opening. From (2) and (3), it comes:

$$F_{1,\text{gripper}} s_{1,\text{gripper}} = F_{2,\text{grasp}} s_{2,\text{grasp}} \quad (4)$$

By considering $F_{2,\text{grasp}} = 50$ N, i.e., at the lower limit of our technical specifications (force theoretically suited to grasp and manipulate waste objects of around 0.5 kg), it results the following new grasp opening:

$$s_{2,\text{grasp}} = \frac{F_{1,\text{gripper}} s_{1,\text{gripper}}}{F_{2,\text{grasp}}} = \frac{125\,\text{N} \cdot 32\,\text{mm}}{50\,\text{N}} \cong 80\,\text{mm} \quad (5)$$

This news grasp opening $s_{2,grasp} \cong 80\,\mathrm{mm}$ fulfills the technical requirements of a total stroke 60÷120 mm.



(a) (b) (c)

Figure 4: Stroke enhancement adapter: (a) perspective view; (b) front view of gripper stroke enhancement adapter in closed position; (c) front view of gripper stroke enhancement adapter in opened position.

As illustrated in Figure 4c, there is still need to improve the shape of the tip of the stroke enhancement adapter, in order to better grasp the object. Another idea is to integrate also FinRay adaptive fingers provided by FESTO.

3. CONCLUSION

A new stroke enhancement adapter has been designed and will be tested in order to collect/grasp waste objects. Being actuated at one side by the FESTO electric parallel gripper EHPS-25 with 125 N for a total stroke of 32 mm, this adapter provides to its other side where the object is grasped a force of 50 N for an increased total stroke of 80 mm. Thus, the stroke enhancement adapter provides a larger stroke, but decreases the grasping force. Further tests will show the reliability of this innovative stroke enhancement adapter. Its shape will be optimized in the next design phase. Another further study direction concerns the coverage of the fingers of this stroke enhancement adapter, which in the new configuration are responsible for the grasping action, with adhesive strips (anti-skidding material), in order to increase the coefficient of friction between the grasped object and the fingers of the stroke enhancement adapter attached to the original gripper.

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