A Novel System for Grasping and Handling Flat and Deformable Objects

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Abstract—**For the automated industry, it is important to develop a new mechatronics system, which is able to grasp and manipulate deformable objects in a reliable way. This paper discusses an idea for developing a concept of gripper exploiting the physical proprieties of the objects to be manipulated such as, for example, fabrics textile, sheets of paper or, in general, Flat and Deformable Objects (FDOs). The idea is to build a gripper prototype, which uses two rotational wheels, microspines placed on the fingertips, in order to buckle and lift up the flat material. The methodology and the type of gripper used will be described in detail.**

Keywords–Flat and Deformable Objects; Grasping; Robotic Manipulation; Friction; Buckling; Microspines; Rotational Hand.

I. INTRODUCTION

Manipulation and grasping of rigid objects is a mature field in robotics, but the study of deformable objects is not so extensive in the robotics community. Unfortunately, deformable objects are extremely difficult to manipulate because they have infinite degrees of freedom [1]. The automation industry has faced this problem and in particular how to manipulate Flat and Deformable Objects (FDOs) such as, for example: garments, fabrics textile, cloths, which require strong skills in handling and, for this reason, are performed mainly by humans [2]. The majority of industries have a great need for simple, reliable, versatile and low cost grippers for grasping and handling these kinds of objects. So, endowing robots able to manipulate FDOs for some specific industry has a great advantage in economic terms. For instance, using these kind of systems reduces the labor cost [3][4] and the physical burden on workers [5][6]. The idea starts from some papers which deal with manipulation of FDOs using a parallel gripper that has two rotational wheels on the fingertips [7] and exploits some ideas used to pick up textile fabrics from layers described [8] and [9]. The choice of using microspine in the gripper is given by the fact that the study in [10] provided very reliable results for grasping and handling flat and deformable materials. The different approach used in this paper exploits an intrusive method using microspines, but also also a non-intrusive method exploiting the friction of the wheels; it is also possible to combine them together. The main purpose of this research is to increase the reliability of the grip of an FDO, but at the same time to make it adaptable. This concept of gripper exploits friction between the rotational wheels, placed on the top of the fingertips, and the flat material to be manipulated in order to transfer the frictional force which is parallel to the plane of the FDO (see Figure 1). This frictional force is proportional to the force contact of the wheel and also depends on the friction coefficient. This kind of gripper is very useful when it is necessary to pick up, for example, a piece of textile fabric from layers. A big inspiration for making the new gripper comes from an interesting work [11] where, in the Jet Propulsion Laboratory (JPL), a lightweight robot which is able to climb rough surface using wheels with microspines has been developed. The interactions between microspines and asperities of the rough surface generate the movement of the robot and, therefore, the idea is to exploit this principle in order to grasp textile fabrics or other FDOs. The material of the wheels that will be used in the novel gripper is one that guarantees a good grip and also works with smooth surfaces.

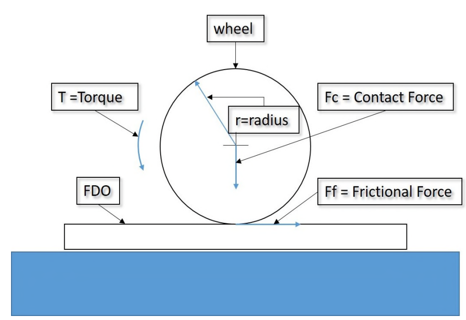

Figure 1. Frictional Force transmitted to the FDO.

II. Description of the Novel Gripper

The gripper is currently at conceptual stage and still a work in progress, but, in the future, it will be completely developed. Figure 4 shows the longitudinal section of the novel gripper in a simplified version in which it is possible to identify the main components for understanding better its working principle. This gripper will be mounted on the end effector of a robotic arm taking advantage of its degrees of freedom for spatial movement. The grasping system chosen is a parallel gripper, widely used for handling in industries, which is simple to build, but very reliable and useful for pinching the object to be manipulated. The gripper will have these basic, but important components:

- A Body
- Two Fingers
- Two wheels
- Microspines

The Body is a structural part of the gripper where components such as, for example, electrical wirings, sensors, actuators and all others movable parts ae mounted. The Two Fingers are mounted in the Body and they are moved thanks to a screw (see Figure 4) which is actuated with a single electrical motor. In this way, it is possible to slide in parallel the two fingers on the Body. At the fingertips, two rotational wheels are placed, each one actuated with an electrical motor. The new concept of gripper is all in the development of the wheels which it will be the key to grasp every FDOs. Inside these two wheels there are placed 12 microspines distributed every $\frac{\pi}{6}$ radians (see Figure 4) which can be extended or retracted rotating the reel where the wires of the microspines are wrapped. The wire of each microspine follows a logarithmic spiral path, inside a hole of the wheel, which has the Cartesian coordinates expressed in the following parametric form:

$$\begin{cases} x(\theta) = r(\theta)(\cos(\theta)) \\ y(\theta) = r(\theta)(\sin(\theta)) \end{cases}$$

where θ is the angle expressed in radians and $r(\theta) = r_0 e^{b\theta}$ is its polar equation. The terms of the polar equation are: r_0 which is the radius where the logarithmic curve starts and b is a parameter for determining the rate of increase of the spiral. The parameter b is expressed in radians because $b = \cot(\psi)$, where ψ is the angle between $r(\theta)$ and the respective tangent of the curve. Figure 3 shows an example when $\psi = 70^{\circ}$ and the interesting aspect is that this angle remains constant so it means that it does not depend on the values of θ and r_0. Figure 2 shows different paths as the ψ angle changes. The variable θ is very useful in order to compute the total length of the spiral. These aspects are very important because it is possible to test the microspines with different angles and lengths in order to have an optimal interaction with the FDO to be grasped and manipulated (as shown in Figure 6). The use of this kind of gripper is particularly interesting when the FDOs considered are textile fabrics or general materials with rough surfaces. It is also possible to manage non rough FDOs as, for example, sheets of paper using wheels in rubber's material, or only their contact surfaces, in order to exploit its high coefficient of friction. In the next section, we explain two methods for picking up FDOs using the gripper described.

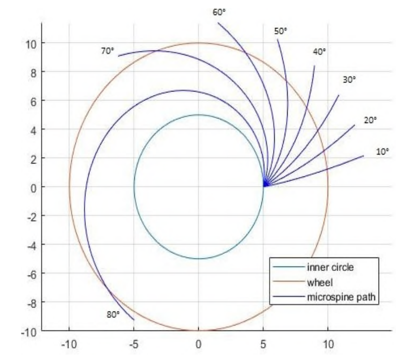

Figure 2. Example of different logarithmic spiral path as the ψ angle changes.

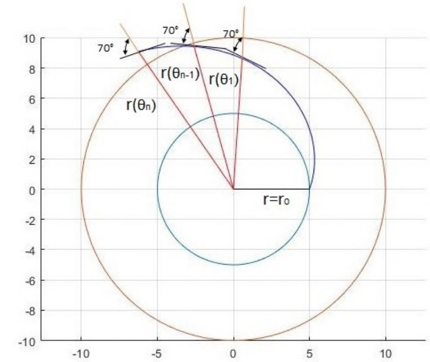

Figure 3. Equiangular spiral path.

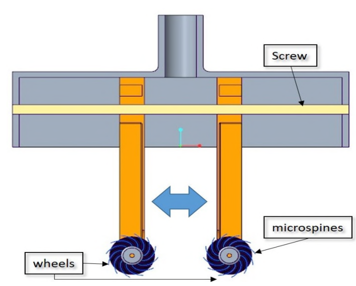

Figure 4. Longitudinal section of the novel gripper.

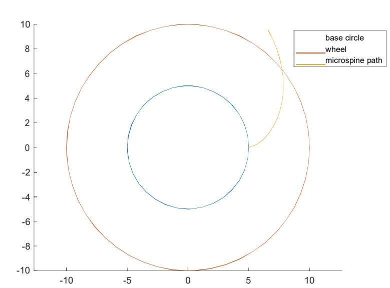

Figure 5. Generation of a single microspine's path.

III. Methodology used in the Novel gripper for grasping

In this section, we explain two different approaches for grasping FDOs using the gripper described in Section II. The first method is very useful when it is not possible to grasp the FDOs at the boundary. Before starting any operation, the thickness of the FDO should be known to be able to manipulate it in order to regulate the right length of the microspines which have to penetrate into the material, as shown in Figure 6. This kind of gripper is studied also for picking up the material from a layer of materials. However, if there is a risk of damaging the FDO by using the microspines, these can be retracted in order to work only with the rubber of the wheels in order to exploit the frictional force generated between the two contact surfaces. The grasping procedure is quite simple and could be synthesized in these few points:

1) Gripper approaching
2) Grasping action
3) Manipulation

In the first point, using a robotic arm, the gripper is moved above the object and its two fingers are opened at an appropriate distance. After that, the wheels are moved down until the wheels lightly touch the FDO and, therefore, a large contact force is not required. In the second procedure, the two wheels are activated to rotate at the same speed in order to allow the microspines to penetrate into the FDO. This action lifts and, at the same time, folds the FDO, as shown in Figure 7. The buckling generated from the torque of the wheels depends on the material considered and it is related to the flexibility of the FDO. Therefore, if the object is too rigid, it will be impossible to use this method. The second method, shown in Figure 8, is quite similar to the first one, but there is a difference with the grasping point of the material. Such point is placed quite near to the boundary. This can be an advantage when it is impossible to grasp it in a different place and, furthermore, it is possible to engage less material during the grasping. The choice of methodology depends on the task that needs to be performed.

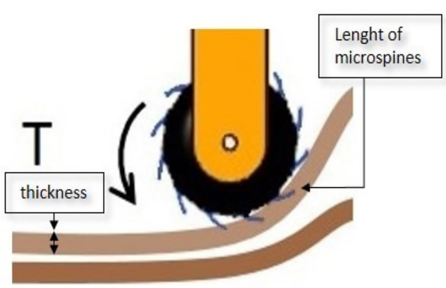

Figure 6. Detail of the interaction between wheels and FDO.

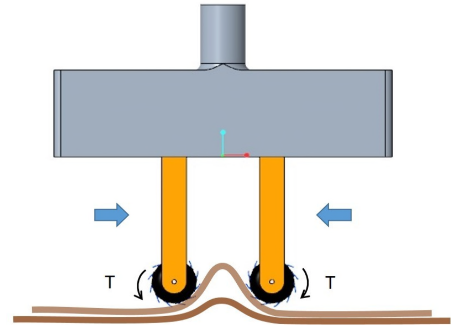

Figure 7. First method in order to Buckle and lift up the FDO.

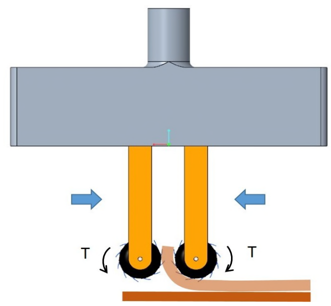

Figure 8. Second method in order to Buckle and lift up the FDO.

IV. Conclusion and Future Works

In this work, we have explained different methodologies that will be used in our gripper for grasping and manipulating Flat and Deformable Objects (FDOs). In particular, we focused on the study of the geometry for realizing the microspines. In the future, we will also study other important aspects such as, for example, the choice of the proper microspines material, its size, etc. This is just a preliminary idea of a gripper and, in the future, it will be studied and developed more, adding all the necessary components useful to produce a prototype able to work in a reliable way. After that, it will be tested in a real scenario using different kinds of FDOs in order to check its performance.

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