FRICTION BETWEEN CYLINDRICAL OBJECTS AND PREHENSION ELASTOMER FINGERS

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Abstract - The human prehension systems realized by two or more fingers are an important inspiration source for development of the performed actuators, especially for prehension of the small objects. In the contact between the fingers and the small objects the adhesion and skin deformation are essentially for a good and precision prehension. Based on the human finger configuration was realized from elastomer artificial fingers to be used in the prehension systems of the robots. In the present paper authors included the methodology to determine the friction forces and friction coefficient between cylindrical objects and an artificial finger. Also, some friction forces and friction coefficients obtained by experiments between elastomer fingers and cylindrical objects have been presented.

Keywords: Elastomer artificial fingers, elastomer friction tests, friction coefficient, friction forces

1. Introduction

The human prehension systems are an important inspiration source for development of the performed robotics prehension systems of the small objects.

The prehension of the small objects by artificial fingers is a complex problem balanced between a minimum prehension force to move the objects as function of the adherence between the artificial fingers and objects and a maximum prehension force to avoid the elastic or plastic deformation of the prehensed objects. A lot of prehension systems based on electrical and pneumatic actuation are developed in the last period [1, 2, 3, 4, 5].

Barnea [6] and Barnea et al.[7] experimentally determined the friction between small cylindrical objects and human fingers. The experiments were realized by using the CETR UMT Microtribometer with small sliding motion of some aluminium and PTFE cylinder. The experiments realized by Barnea evidenced that the adhesion and sliding processes are influenced by the nature of the cylinder materials and normal load. So, for aluminium cylinder the dynamic friction coefficient have values of 0.8 and 0.4 for the normal load having values between 1 N and 4 N, respectively. For PTFE cylinder the dynamic friction coefficient have values of 0.4 and 0.2 for the normal load having values between 1 N and 4 N, respectively. Also, the experiments evidenced that in the sliding process between a cylindrical object and a human finger especially “butterfly” diagrams have been obtained as a result of the successive elastic deformations and relaxations of the finger skin.

Rusu et al. [8] evidenced the similar “butterfly” configuration between steel and aluminium cylinder in contact with a plane PDMS elastomer. Based on the human finger configuration Barnea [6] realized from elastomer some artificial fingers to be used as surface elements in prehension systems. Also, Barnea realized a lot of experimental investigations and evidenced complex behaviour of the friction process between small cylinders and elastomer material used for artificial fingers.

In this paper are presented the methodology, experimental equipments and some important results regarding the friction of small carbon cylinder in sliding contact with an artificial finger realized by an elastomer.

2. Experimental methodology and testing equipments

In Figure 1 is presented the experimental equipment consist in the Microtribometer CETR UMT-2 with following accessories:

- a force sensor DFM2 to detect the force on Z direction – normal force and force on Y direction – friction force;
- a pin fixed by a special support on the force sensor;
- a cylinder attached on the top of the pin;
- a special support to maintain in a fixed position of the artificial finger;
- the linear table of the Microtribometer with linear cyclic motion in the Y direction.
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The artificial finger is fixed on the support and the cylinder is pressed on the finger with normal forces between 1N to 4N as is presented in Figure 2. The artificial finger realizes a cyclic sliding motion with the linear table in the direction of the Y axis on a total distance of 6 mm. The speed of the table was of 1 mm/s and five normal load Fz were used: 1N, 2N, 3N, 4N and 5N. A carbon cylinder having diameter of 6 mm has been used for friction tests. A detail of the carbon cylinder and artificial finger contact is presented in Figure 2.

According to the Tribometer sensor the sign of the tangential force Fx is positive or negative depending of the sliding direction. In Figure 3 are presented the positive and negative variations of the tangential forces Fx during the period of 60 seconds for all five normal loads Fz.

It can be observed that tangential force Fx have a succession of three different behaviours: an elastic deformation in the motion direction of the elastomer, a sliding zone and an elastic relaxation of the elastomer. The sliding zone has a long period for normal force Fz = 1N and, by increasing of the normal force the sliding zones are reduced. We consider that by increasing the normal load the elastic deformation is the dominant component of the tangential force and sliding component cover a smaller zone. To be more evidence the successive behaviors of the elastomer finger during the movement in contact with the carbon cylinder the variation of the tangential forces Fx are presented as function of the distance Y.

The variations of the tangential forces Fx along the distance Y for all linear cycles realized during 60 seconds for a normal force Fz = 1N and for a normal force Fz = 5N are presented in Figure 4 and Figure 5, respectively.

A complete linear cycle start initially in the point O* and after first cycle in the point O. The distance OA (or initially O*A) corresponds to the elastic deformation of the finger in the motion direction characterized by a continuum increasing of the tangential force Fx. From the point A to the point B (end of the distance Y = 6mm) the tangential force Fx have an approximate constant value that means presence of the sliding of the cylinder on the finger.

3. Experimental results and comments

During the experiments were determined the variation of the tangential force Fx developed as a result of the artificial finger movement in positive and negative Y direction.
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By the Microtribometer software, the ratio between absolute value of the tangential force $F_x$ and normal force $F_z$ are considered as a friction coefficient $COF$ and can be presented as diagrams function of time or the distance $Y$. In Figures 6 and 7 are presented the diagrams of the variation of friction coefficient $COF$ as function of distance $Y$ for the normal force $F_z = 1N$ and $F_z = 5N$, respectively.

Both in Figure 6 and in Figure 7 it can be observed that exist important variation of the indicated friction coefficient $COF$ during the distance $Y$. So, on the point $O^*$, $O$ and $C$ the indicated friction coefficient is zero, that is not physically correct. In these points the tangential force is zero, as a result of the change the sliding direction and, as a consequence the ratio between $F_x$ and $F_z$ is zero.

Also, the zones of increases or decreases the indicated friction coefficient $COF$ corresponds to the elastic deformation and relaxation of the elastomer without the sliding motion, the adhesion between cylinder and elastomer being dominate. In the zones having approximate constant values (zones AB and DE) the cylinder start to slide over the elastomer and the friction coefficient $COF$ have physical signification.
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Figure 5 Variations of the tangential forces in cyclic motion on 6 mm distance, for normal load of 1N and for linear speed of 1 mm/s

For normal load $F_z = 1$ it can be observe that the real friction coefficient obtained in the positive direction (zone AB) have values between 0.28 to 0.3 and in the opposite direction (zone DE) have values between 0.35 to 0.42. By increasing of the normal force $F_z$ from 1 N to 5 N the real friction coefficient decreases having values between 0.3 to 0.32. Also, no important differences for the friction coefficient in the two direction it can be observed.

For the normal load $F_z = 5$ N, as is presented in Figure 7, the “butterfly” configuration of the friction coefficient variation has been obtained. Similar “butterfly” configurations but for the friction force as function of the distance $Y$ have been obtained by Barnea [7] for the friction and adherence between cylindrical objects and human finger.

Figure 6 Variations of the tangential forces in cyclic motion on 6 mm distance, for normal load of 1N and for linear speed of 1 mm/s

Figure 7 Variations of the tangential forces in cyclic motion on 6 mm distance, for normal load of 1N and for linear speed of 1 mm/s

4. Conclusions

The prehension of the small cylindrical objects by artificial elastomer fingers implies complex friction and adherence problems.

By using artificial finger the authors evaluated experimentally the friction and adherence of a small cylindrical object in contact with the finger, loaded with normal forces between 1N to 5 N and sliding with a linear speed of 1mm/s.

Following remarks can be made after the experiments:

1. The authors developed an original methodology to determine by experiments the friction and adherence between small cylindrical objects and artificial finger.
2. A succession of the adhesion zone with elastic deformation of the elastomer followed by a sliding processes has been observed in the motion of the loaded cylinder on the finger in one direction. By change the direction, the elastomer have an elastic relaxation followed by an elastic deformation as result of adherence. A new zone with sliding process between the cylinder and elastomer appears to the end of the stroke.
3. The real physical friction coefficient is considered only in the sliding zones and has values between 0.3 to 0.42, as function of the normal load.
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By increasing of the normal load from 1 N to 5 N the friction coefficient decreases from 0.42 to 0.3.
4. The “butterfly” diagrams have been obtained as a result of the successive elastic deformations and relaxations of the artificial finger.

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6. References