EXPERIMENTAL ANALYSIS OF SOFT PADS FOR ROBOTIC FINGERS

P. Tiezzi  G. Vassura
D.I.E.M – University of Bologna
Viale Risorgimento 2, 40136 Bologna, Italy
paolo.tiezzi@mail.ing.unibo.it  gabriele.vassura@mail.ing.unibo.it

Introduction. The importance of compliance and friction properties of robotic finger pads in order to enhance grasp stability and robustness has been widely remarked in previous research [1, 2, 3]. In order to develop robotic fingers with soft pads some important indications can be obtained from the analysis of the human finger behavior [4]. Biologically-inspired robotic fingers will be characterized by an internal rigid structure covered by a thick soft layer and by an external thin epidermal layer. Engineering approaches able to consider all the aspects that concern design of soft robotic finger are completely absent in the literature. In this work guidelines for a systematic evaluation of fingertip design alternatives are proposed and discussed. Special purpose equipment, developed in order to test the alternative fingertip solutions, is described and early experimental results are commented.

Test program for comparative evaluation

A functional evaluation of the whole fingertip structure must consider all the main functions that are involved in grasping tasks:

- contact application;
- contact holding;
- contact removal.

Each function can be related to some basic properties of the fingerpad, that can be classified in two main families.

1. Properties related to the capability to quickly adapt on the object surface during contact application and to quickly recover the initial shape after contact removal:
   1.1 conformability on sharp edges;
   1.2 velocity of contact adaptation.
   3.1 shape recovery after contact removal.

2. Properties that concern the capability to resist to external loads and disturbances in order to guarantee the object restraint:
   2.1 robustness against tangential and rotational slipping;
   2.2 robustness against dynamical disturbances;
   2.3 resistance to rolling.

A comprehensive methodology for the comparative evaluation of alternative fingerpad design has been developed [5], based on the guidelines of the VDI 2225 recommendation for systematic approach to design.

Experiments on fingertip behaviour

Tests can be conducted on simplified fingertips (see Fig. 1) that have a hemispherical geometry and a constant thickness of soft layer bounded to the rigid inner structure. Preliminary investigation allowed to determine the acceptable range of variation of design parameters (thickness of soft pad and radius of curvature) and material (its softness and visco-elastic behavior).

For experimental activities the development of a purposely-designed equipment was necessary.

With reference to Fig. 2a, in the proposed equipment two fingertips are symmetrically applied on the opposite faces of the reference object in order to investigate the contact mechanics under normal and tangential loads. Besides the evaluation of contact robustness with respect to linear sliding due to overcoming of friction limits, the analysis of object displacement can provide useful measure of normal and tangential stiffness of contact. Dynamic response can be investigated by the experiment described in Fig. 2b, in which the object is hit with an impulsive force and its displacement is monitored. Analysis of the response curve allows the evaluation of internal damping.
The test equipment, which holds the two fingertips, is composed by two counteracting four-bar linkages (see figure 3), with low friction joints, that guarantee the symmetry of both displacements and loads. Between each fingertip and the relative holding linkage a multi-component force-torque sensor is placed that allows complete monitoring of the applied forces and torques. A system of contact-less proximity sensors is adopted in order to continuously monitor the displacements of both the fingertip and the reference object. A rolling-diaphragm pneumatic actuator applies disturbance loads on the reference object, while on the fingertips the loads normal to contact surface are applied to each linkage with weights activated by a second pneumatic cylinder. The system guarantees a correct approach to the contact surface and a good control of applied loads with acceptable repeatability.

Figure 3

Advantages of such test equipment architecture are the capability to perform tests both on surface properties and on static and dynamic behavior of the pads, the absence of disturbing effects, the complete reproduction of operating conditions, the relatively low complexity of test equipment.

Preliminary results

Preliminary experiments to evaluate the effectiveness of the proposed methodology and equipment were performed comparing the behavior of two different elastic silicon rubbers:

- rubber A (hardness 18 Shore A);
- rubber B (hardness 20 Shore 00).

For each material 1.5, 3 and 6 mm thick layers have been tested. Examples of experimental results are described in figures 4 and 5. Figure 4-left shows the behavior of the fingertip under application of increasing normal loads, measuring the flattening of the fingertip hemisphere. The highly non-linear behavior is fully according to previous results described in [6] and by other authors. Figure 4-right shows the variation of tangential displacement of the reference object under the application of tangential loads. The region of linear dependence between displacement and tangential load is quite evident for a given normal load: as the normal load changes, a roughly quadratic dependence between tangential stiffness and normal load can be observed.

Figure 4

Conclusions

The proposed methodology and test equipment seem very promising. Preliminary experiments have fully confirmed the feasibility and the practical interest of this approach, especially when comparison between different fingertip designs must be done easily and quickly.

Acknowledgments

The authors gratefully acknowledge the contribution of Dr. F. Lotti from DIEM, Dr. L. Bagiotti from DEIS, technicians V. Ciavatti, S. Monti from DIEM.

Reference