

## High Dexterity Underwater Gripper



## **1. Foreword**

The High Dexterity Underwater Gripper is an advanced underwater gripper specially developed to be able to perform complex manipulative tasks and to allow the grasping and manipulation of soft, fragile objects.

The High Dexterity Underwater Gripper is based on a electrohydraulic actuation technique (the Direct-Electric-Drive Fixed-Volume Closed-Circuit Hydraulic System), proprietary of Eureka Engineering Srl, La Spezia, ITALY.

A prototype of the High Dexterity Underwater Gripper has been developed by Eureka Engineering Srl as a subcontractor of DIST-UNIGE in the AMADEUS II project (MAST programme).

The AMADEUSII prototype features three two-Degree-Of-Freedom fingers, anyway the technique lends optimally itself to the implementation of simpler (e.g., 3 x 1DOF fingers) or more sophisticated designs.

## **2. Brief description of the actuation technique**

The Direct-Electric-Drive Fixed-Volume Closed-Circuit Hydraulic System is based on the use of a hydraulic circuit formed by two flexible bellows coupled by a flexible line.

One the bellows (master) is coupled to the electric drive while the other (slave) is coupled to the device to be operated.

The circuit formed by the two bellows and the connecting line, is completely filled with hydraulic fluid; being this fluid virtually non-compressible, the circuit results not only a closed-circuit but also a fixed-volume one.

Thanks to this, the system shows the following main features:

- a force applied by the electric drive to the master bellows is transmitted to the slave bellows, virtually with no loss
- the slave bellows is forced to copy the same mechanical motion of the master bellows.

To achieve a wide bandwidth of the actuation system, the master bellows is driven by an electric linear motor directly coupled to it.

Thanks to the DEDFVCCHS actuation technique, the gripper shows some special features:

- **high dexterity**: the backlash-free, friction-free and wide bandwidth operation of the actuation system allows the gripper to attain the fast-response and fine motion characteristics required to perform complex manipulative tasks
- **fine contact force control**: thanks to the absence of dynamic seals, the gripper's operation results friction-free, allowing for a fine control of the contact force
- **pressure-compensation**: due to the fact that the same ambient pressure applies on the two bellows in the same way, the actuation system is intrinsically pressure-compensated

### **3. Gripper detailed description**

The gripper system is formed of two main sub-systems:

- the articulated gripper
- the electrohydraulic drives assembly

#### **3.1. Articulated gripper**

The articulated gripper is formed of

- the palm
- the three fingers

##### **3.1.1. Palm**

The palm provides the mounting base for the three fingers, positioned equally spaced at 120° to each other.

The mechanical interfacing to different robotic arms is easily achieved by the use of a customized mechanical adapter.

A miniaturized underwater video camera can be housed into the mechanical adapter to provide a close-up monitoring of the manipulator operation.

##### **3.1.2. Finger**

Each finger is actuated by three slave bellows housed inside its structure.

The finger is formed of two parts, a fixed part and a moveable one; these parts are joined by a cardan (universal) joint, allowing a 2 degree-of-freedom motion.

The moveable part is, at rest, aligned with the fixed one and, thanks to the joint, is free to move inside a cone having the axis coincident with the axis of the fixed part, the vertex located at the center of the joint and a half-width of about 25 degrees.

The fixed part carries the connectors of the hydraulic lines and is mounted to the palm.

The moveable one carries on its free end, the tip, an elastomer termination. The tip's shape, a rounded-edges pyramid, skewed toward the center of the gripper and topped by a hemisphere, is optimized for the manipulation and grasping of objects having different size and shape; moreover the characteristics of the elastomer help to increase the low-contact-force grasping capability.

## 3.2. Electrohydraulic drives assembly

The electrohydraulic drives assembly is formed of nine identical units, one for each of the bellows in the gripper, and of the mounting cage

### 3.2.1. Electrohydraulic unit

The enclosure of the electrohydraulic unit is cylindrical in shape; one of the two end-plates carries the connector of the hydraulic line, while the other one carries the liquid-tight electrical cable connector and the inlet of the pressure-compensating device.

The enclosure houses: the pressure-compensating device, the electrohydraulic drive, the position sensor and an electrical board carrying the cabling interconnection terminals.

The pressure-compensating device is formed by a flexible bellows mounted liquid-tight to the inner side of the end plate.

The electrohydraulic drive is formed by the master bellows, the linear electric motor and the position sensor.

The linear electric motor is of the voice coil type, more specifically is of the moving-coil type; that is, the motor stator houses the permanent magnets and forms the magnetic circuit, while the coil moves inside the gap of the circuit.

The master bellows and the linear motor are placed on the same axis, and the moveable end of the bellows is directly coupled to the coil assembly, so friction and backlash phenomena are avoided.

A miniature LVDT (Linear Variable Differential Transformer) linear position sensor is used to accurately measure the motion of the moveable end of the bellows.

### 3.2.2. Cage

The cage allows the tightly packed mounting of the electrohydraulic drives assembly; the nine drives are disposed in a 3 X 3 array configuration.

The cage is provided with handles for transportation, and makes it easy to mount and fasten the assembly on board of an underwater vehicle.

The hydraulic lines bundle, 3m in length, allows the installation of the gripper on many of the currently available underwater robotic arms.



#### **4. Specifications**

Grasping range (spherical object): up to 140mm diameter

Grasping force: 0 to 10N

Power requirements: 24 VDC, 30 A

Dimensions:

gripper: 250 (l) x 200 mm (dia) [approx.]

electrohydraulic drives assembly: 500 x 380 x 450 mm [approx]

Weight: 35 kg [approx]

