Proximity and Force Characteristics of CMC Touch Sensor with Square/Dome-shaped Sensor Elements
T. Kawamura, N. Inaguma, Y. Kakizaki, H. Yamada and K. Tani
Department of Human and Information Systems, Gifu University, Japan

Outline
1. The characteristics of CMC touch sensor with respect to its proximity and force senses were investigated.
2. The relationship between the output of the CMC sensor with the square-shaped sensor element and the distance between the sensor element and an object was determined, and the CMC sensor was able to measure the distance on the order of millimeters.
3. The relationship between the output of the CMC sensor with the dome-shaped sensor element and the force variance applied to the sensor element was clarified, and the CMC sensor was able to measure the force variance in the range of approx. 7 to 25 gf.
4. In future work, a tactile sensor that has the senses of force and proximity will be developed for a robot to grip an object.

CMC Touch Sensor
Carbon Micro Coil (CMC) touch sensor was developed by CMC Technology Development Co., Ltd. The sensor elements are made of silicone rubber and each sensor element contains 10 percent CMCs by weight. One of the elements is a square 30 mm on a side and 3 mm thick; the other is a dome 16 mm in diameter and 2 mm height. CMCs in a sensor element contribute to the electrical conductivity and the sensor element is considered to constitute an LCR circuit. When an object approaches to the sensor element or touches and deforms the sensor element mechanically, the impedance in the LCR circuit changes. The CMC sensor signal processing device (CMC Technology Development Co., Ltd.) detects the impedance changes by measuring the modulation of amplitude and phase of an input excitation signal to the sensor element. The CMC sensor also creates voltage signals of the R- and LC-components separately according to the amplitude and phase modulation.

Proximity Characteristics of CMC Touch Sensor
In the experiment, an acrylic plate is installed on a steel block as an object, and the output of the CMC sensor is sampled when the object approaches to the square-shaped sensor element by the X-stage driven at the velocity of several millimeters per second.

The CMC sensor’s output when the object approached to the CMC sensor element. The object was first located at the distance from the sensor element of 20 mm and the CMC sensor’s output was set to 0 V. $V_g$ increases and $d$ decreases as the object approaches to the sensor element.

To investigate the influence of the velocity of object’s approach, when the object approached at different velocities, the CMC sensor’s outputs were measured at different distances to the object. The CMC sensor’s output measured at each distance almost keep constant regardless of the velocity.

Force Characteristics of CMC Touch Sensor
In the experiment, the CMC sensor and the force sensor samples the difference in the CMC sensor’s output and the difference in the force sensor’s output simultaneously before and after each fine deformation is applied to the dome-shaped sensor element in addition to a constant compression force.

The relationship between the difference in the CMC sensor’s LC-component and the difference in the force sensor’s output (force variance). The difference in the force sensor’s output and the difference in the CMC sensor’s LC-component increase linearly as the fine deformation increases.

The relationship between the sensor force’s output and the CMC sensor’s output for fine deformation within the range of 1 to 5 µm and for compression force within the range of 100 to 200 gf. The equation that estimates force variance of CMC sensor element is as follows:

$$\Delta F = 90.63 \times \Delta V_{LC} \quad (2)$$

The force variance estimated from the output of CMC sensor’s LC-component using Eq. (2). In the experiment, each fine deformation was applied twenty times repeatedly to the sensor element in addition to a constant compression force. The CMC sensor was able to measure the force variance in the range of approx. 7 to 25 gf.