Asymmetric Acceleration Drive in Various Directions on a Plane Using 2-DOF Linear Oscillatory Actuator
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Introduction
1. Back Ground and Previous Research
Haptic -sense of touch- feedback devices without grounded structure have been designed recently. However, these devices are not suitable for incorporation into mobile devices because of their size or require complex control.

2. Application of Haptic Feedback

Grounded type
○ Precisely force control
○ Multi-DoF
× Necessary to fix

Non-Grounded type
○ Portable
× Complex control
× Can’t generate unidirectional force

• Proposal linear oscillatory actuator that can be driven in various directions on a plane.
• Clarification of the dynamic characteristics of the actuator under asymmetric acceleration method for non-grounded unidirectional force feedback drive by using 3-D FEM analysis.

Proposed Actuator

Basic Structure and Operating Principle

Analyzed Model and Condition

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of elements</td>
<td>500,800</td>
</tr>
<tr>
<td>Number of edges</td>
<td>660,492</td>
</tr>
<tr>
<td>Number of steps</td>
<td>9,959</td>
</tr>
<tr>
<td>Time division (sec)</td>
<td>0.010</td>
</tr>
<tr>
<td>Total CPU time (hour)</td>
<td>2.60</td>
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</tbody>
</table>

The thrust of the mover is calculated using the Maxwell stress tensor method, and is substituted into motion equations. The position of the mover is calculated at each time step.

Results
1. Static Analysis

These results show this actuator has good controllability that doesn’t depend on the position of the mover.

2. Dynamic Analysis

Using the proposed actuator, drive to obtain haptic feedback was simulated. A voltage that generates an asymmetric acceleration was applied.

In single axis drive, an asymmetric acceleration observed without interference between the axes.

Biaxial drive

When both axes were operated concurrently, the acceleration waveform has almost the same shape as during single axis drive. These results show that the generation of asymmetric oscillation in various directions on a plane is possible.

Conclusion

• Small-sized two-DOF oscillatory actuator is proposed.
• The static and dynamic characteristics of the actuator are calculated by 3-D FEM. Asymmetric acceleration for illusion of haptic feedback can be observed.
• In the near future, we will make a prototype and verification of this actuator’s dynamic characteristics will be conducted by comparing the empirical data with that from 3-D FEM analysis.