A proposal of a dynamic mass measurement method based on adaptive stiffness adjustment

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Recently, experiments in biology and materials science have been conducted in the microgravity environment of orbiting space shuttles or space stations. In these experiments, mass measurement of an object is a basic requirement in almost every scientific field. Mass measurement methods based on gravity can not be utilized in microgravity. Therefore, several mass measurement methods have been proposed so far. In those methods, collisions, oscillations and centrifugal force are used to measure the mass of the object in microgravity.

However, there are two problems from a practical viewpoint. The first problem is reaction force which works from the measurement system to the space station. If the reaction force can not be ignored, it makes a serious problem with stability of the position and the attitude of the space station. The second problem is that position, velocity and acceleration signals of the measurement system contain noise and it worsens the accuracy of mass measurement. To avoid the first problem, some methods based on anti-resonance have been proposed. In the anti-resonance mass measurement methods, the reaction force converges to zero. Thus the anti-resonance method is suitable for mass measurement in microgravity. However, the second problem with signal noises still remains. Moreover, the previously proposed methods based on anti-resonance require the accurate physical parameters of the measurement system.

To overcome such problems, a new mass measurement method in microgravity based on anti-resonance is proposed in this thesis. Since the proposed method in this thesis utilizes anti-resonance, the reaction force from the measurement system to the space station does not work after the motion converges to an anti-resonance mode. Furthermore, neither the signal such as position, velocity, and acceleration nor the physical parameter of the measurement system is directly used for mass measurement in the proposed method in this thesis. Instead of using those values, the elastic value is mechanically adjusted in order to generate an anti-resonance mode and the mass of the object is estimated through the elastic value and the frequency of the anti-resonance.

In this thesis, a new controller including adaptively adjusted elasticity is proposed to make an anti-resonance mode. It is mathematically proven that the motion converges to an anti-resonance mode basing on a Lyapunov function. Next, the property of the proposed method in this thesis is investigated through some simulation results. Furthermore, two types of measurement system are developed by using blade springs. The performance of each developed system is demonstrated by several experimental results.