A Study on Contact Behavior of ANCF Flexible Beams nstructions

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Abstract

In recent years, the solar sail, which is able to control its attitudes by irradiating sunlight onto membranes, has drawn attention in the fields of astronautics. The membrane is folded when carried into space and deployed in space so that it can realize low transportation cost. Since the shape of the membrane affects the ability of the control, it is important to grasp the behavior of the deployment. Because of air friction and gravity, however, it is impossible to examine the deployment on ground. Therefore, numerical simulation is used to analyze the deployment behavior. As a major numerical simulation method, the Multi Particle Model is used since it has low calculation cost and easy modeling [1]. This model can simulate the deployment behavior with short time. On the other hand, its accuracy can decrease in local area due to its simplicity. Thus, it is necessary to propose complemental methods which can analyze the dynamic behavior of the sail with high accuracy. In this research, Absolute Nodal Coordinate Formulation (ANCF), which is a type of nonlinear Finite Element Method, is used [2]. ANCF is an analysis method to simulate large deformation and rotation accompanied by rigid body motion. ANCF has larger calculation cost and higher accuracy compared to MPM.

One of the factors to affect the deployment behavior is contact. As for sails equipped with comparatively stiff devices such as solar cells or antennas, the fold pattern is designed to make the devices equip efficiently. The dynamic simulation for this type of the sails should consider the contact model since the fold pattern can easily cause contact. Therefore, this study aims to propose the simulation model formulated by ANCF in consideration of the contact model which can be adaptable to the deployment simulation of the solar sail. As a fundamental step of the membrane analysis, this study focuses on a planar ANCF beam, which is assumed as the cross section of the membrane as shown in Fig. 1.

The contact model used in this research is based on Node-To-Segment contact [3]. In this method, the closest point of two objects is defined by solving the optimization problem. For the contact force, the Penalty Method is used, which can express contact forces at arbitrary points on the element with stable calculation. Some necessary terms for the thin flexible beam to introduce the contact model is considered as below.

1. The model can properly express the contact with both side of the beams.
2. The model can correctly calculate the penetration against nonlinear behavior of the beams.

In order to deal with these terms, analysis method with two conditions shown below are proposed in this study.

The direction of the penetration is converted when detecting change of the relative position of the beams.

1. The domain of the contact is bounded around the small area from the beams.

In order to confirm the effectiveness of the proposed method, 3 cases of analysis are conducted as shown in Table 1. The analysis model is shown in Fig. 2. Two beams are contacted with one beam has initial velocity at a node and another beam is at rest as initial state.

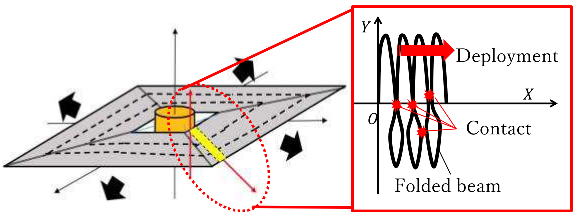

Figure 1. The ANCF beam.

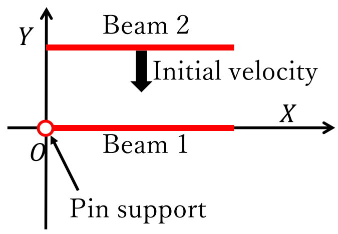

Figure 2. Analysis model.

Table 1. The contact conditions for each case.

Case 1	Case 2	Case 3
Condition 1 & 2	Condition 2	No contact model

The configurations of the beam at $0.01, 0.19, 1.80, 2.00$ [s] are shown in Fig.3. The first contact occurs at 0.19 s. In Case 3, the beam 2 penetrates beam 1 without contact because the contact model is not considered. At 1.80 s, the beams contact each other with different side from the first contact. In Case 2, the direction of the contact is not corrected and leads to the incorrect contact force while the beams correctly contact in Case 1. The histories of the total energy of the system are shown in Fig. 4 and Fig. 5. In Case 2 in Fig. 4, because the direction of the penetration is calculated incorrectly, the excessively large energy of the contact model is added to the system and causes the divergence of energy. In Case 1 in Fig. 5, the change of the energy is sufficiently small compared to Case 3, which has the change of the energy only caused by the error of the modeling of ANCF. Therefore, the two proposed conditions for the contact model can be effective for the thin flexible beam in view of the energy conservation.

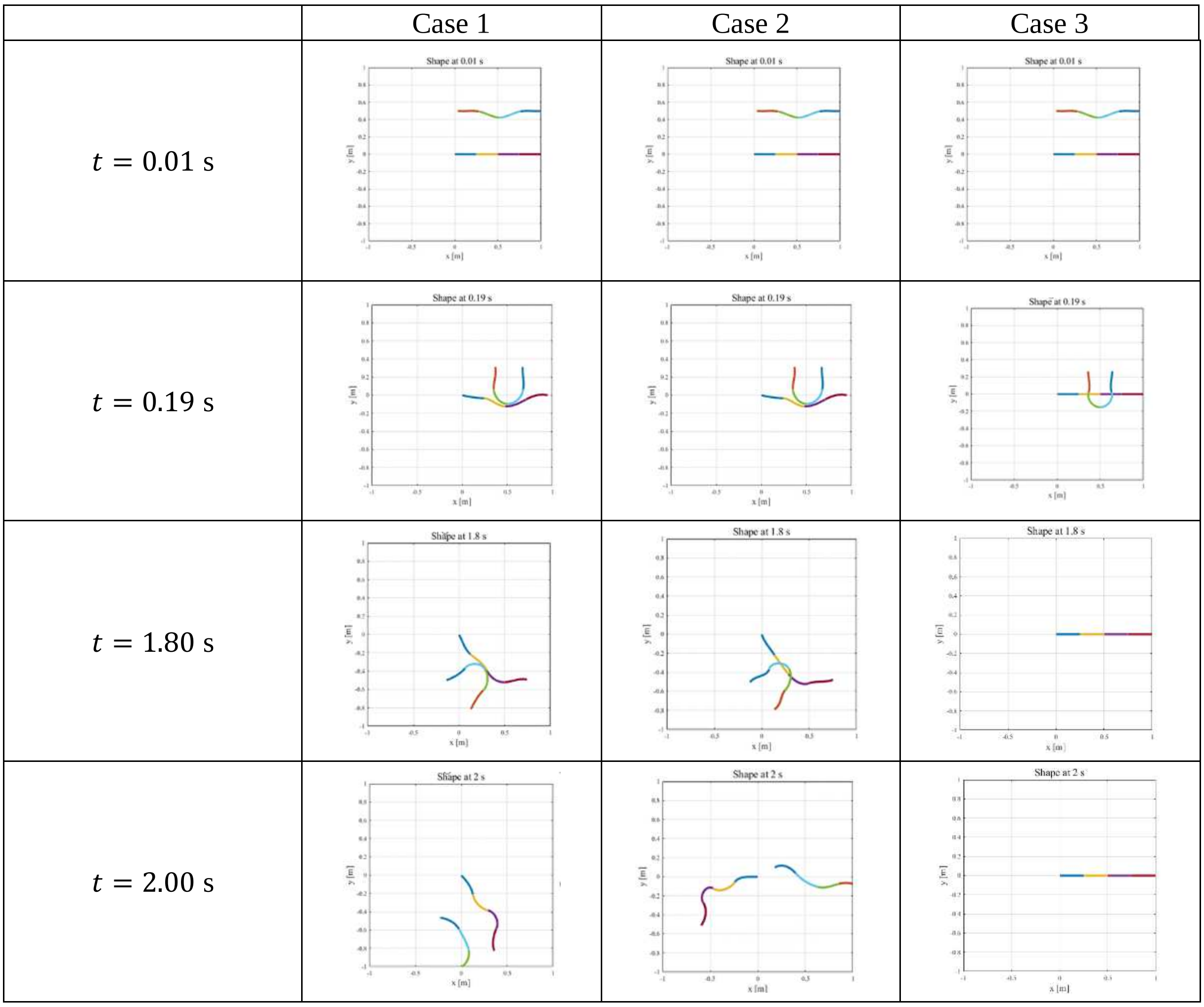

Figure 3. Configurations of the beam in each case.

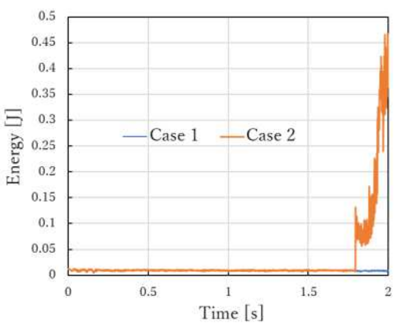

Figure 4. Energy history of Case 1 and Case 2.

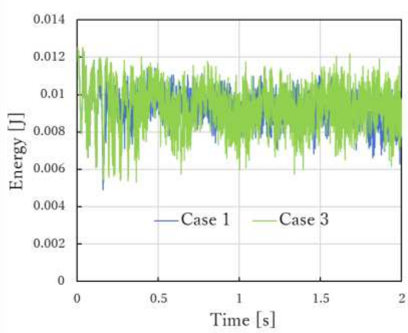

Figure 5. Energy history of Case 1 and Case 3.

References

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