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Nondimensionalized approach for flexible body motion with time-varying length and variable boundary

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Tethered system is a multibody system in which plural components are connected via flexible tether. In such systems, which are primarily used for deep-sea and space exploration, the ability to perform accurate work is largely dependent on the ability to comprehend its flexible motion. In addition, since flexible body systems are also intended for use across different environments, such as air and water, it is necessary to consider their environmental boundary point. However, it is difficult to conduct realistic experiments with such systems, which means that efficient and accurate numerical analysis methods are essential. In this paper, a numerical analysis method for flexible body motion with large deformation/ displacement/rotation and time-varying length that exist in two different environments is proposed. It is based on a conventional method that combines the Variable-domain Finite Element (VFE) scheme with the Absolute Nodal Coordinate Formulation (ANCF) to produce the VFE-ANCF that is commonly used to express flexible body motions [2][3]. However, the VFE-ANCF has accuracy and calculation cost problems when considering environmental boundary movement. In contrast, in our proposed method, which we have named Variable Boundary VFE-ANCF (VB-VFE-ANCF), these problems are avoided by virtually dividing one flexible body into two bodies, above and below the environmental boundary. In other words, each body is always in its proper environment because the two bodies vary in length with boundary movements and flexible body length changes. Furthermore, to eliminate analysis accuracy effects resulting from change in the frequency region caused by body length changes, nondimensionalization is conducted using each body length as a representative value. The relationship between the difference in the displacement of end point ε^* and the dimensionless boundary movement speed α^* is shown in Fig.1, where it can be seen that the ε^* value is small and that our proposed method can perform numerical analysis that considers boundary movements while maintaining accuracy. In addition, the closer α^*gets to $\mathrm{V}^* L_{A0}/L_0$, that is, the smaller the constraint and inertial forces that are generated by virtually considering one flexible body as a multibody system with two bodies, the smaller ε^* value. Note that V^* is the dimensionless flexible body length change speed, while L_{A0} and L_0 are the initial lengths of body A and the flexible body, respectively.

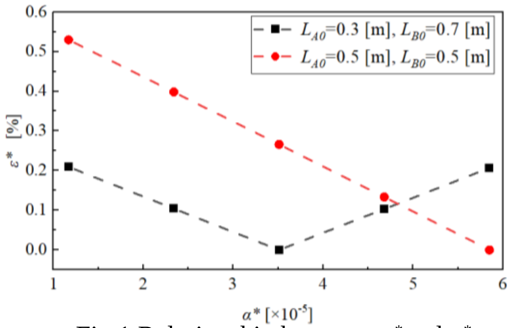

Fig.1 Relarionship between $\alpha^*$and ε^*

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