Title	多軸自在継手を用いた可変構造の形態解析および一般逆行列に基づく流体解析
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Abstract

In many engineering problems, it is necessary to solve simultaneous linear equations. In this approach, to obtain a precise solution, the number of unknown quantities must be equal to the number of equations, and the inverse matrix of these equations must be defined. This calculation condition is required for a consistent system.

However, the linear system referred to as an underdetermined system, which does not possess a sufficient number of equations for the unknown quantities, is composed of the some discretization methods using partial differential equations for physical phenomena. Another linear system is the overdetermined system, which has more equations than unknown quantities. A useful method for solving all these problems is the unique Moore–Penrose generalized inverse matrix method.

The Moore–Penrose generalized inverse matrix is a versatile inverse matrix, which can provide the optimum solution, which is sometimes unique, regardless of the type of linear system being considered. Hence, the Moore–Penrose generalized inverse matrix can be applied to a wide variety of engineering problems, including fluid–structure coupled problems, provided that the accuracy and computational work load are adequate.

This thesis discusses the usefulness of the Moore–Penrose generalized inverse matrix on the basis of a numerical analysis of the physical phenomena that occur in structures and fluids.

Initially, I treat variable-geometry structures and propose the method of the shape-finding analysis of variable-geometry structures. This proposed analysis is based on a displacement method in which the unknown quantities are defined with the displacement vector. In general, this analytical model of variable-geometry structures becomes an underdetermined system due to a lack of boundary conditions. However, variable-geometry structures unavoidably have some small offsets between the rotational centers of the links.

In this manner, variable-geometry structures pose these difficult problems. Therefore, we propose a joint system called the “multilink spherical joint,” which can form an ideal truss structure without offsets. Forming this structure with a multilink spherical joint satisfies the requirement for the behavior of ideal truss structure models.

Subsequently, I propose the shape-finding analysis of variable-geometry structures based on the analysis of the stabilizing process for an unstable structure. In previous research, this analysis of the stabilizing process has been applied to one-dimensional elements functioning with a rigid body. However, in this thesis I define the virtual material of a one-dimensional element as a rigid body and extend the results to the case of multi-dimensional elements. In this manner, the numerical analysis makes it possible to show the variable behavior of structures with an incompressible body. I also validate the proposed method by applying it to the analysis of a catenary.

The method is also modified for the case of fluids. I propose an analytical method for an incompressible fluid using the Moore–Penrose generalized inverse matrix. We typically use the separating method in a fluid analysis, which means that we calculate the velocity and the pressure separately. In this method, we do not calculate the inverse matrix, because of the large calculation load, but instead use the iteration method.

However, there are difficult problems with an artificial boundary condition such as assuming an infinite distance. In such problems, there is some possibility of using the Moore–Penrose generalized inverse matrix because it can be applied without boundary conditions.

In this thesis, I propose an algorithm for solving the Navier–Stokes equation by calculating the Moore–Penrose generalized inverse matrix and the velocity mode matrix, whose values are given by the equation of continuity. This method is based on simplified mercer and cell (SMAC) method, and I validate it by solving the cavity flow problem, which is considered to be a benchmark test in fluid analysis, and by comparing it with Ghia’s numerical value. In addition to the above two physical phenomena, I treat the fluid–structure interaction problem as quasi-static. The results of this problem indicate the ponding phenomenon that occurs in the membrane structures.

As a result of these numerical solutions, I can conclude that these proposed methods are appropriate. Therefore, it is shown that the method of numerical analysis using the Moore–Penrose generalized inverse matrix is useful for not only a structure analysis but also a fluid analysis. However, it is difficult to determine the most efficient method for fluid analysis because of the large computational load required to calculate the Moore–Penrose generalized inverse matrix. In the future, I believe that this method will prove useful for the wind and variable-geometry structure interaction problem.