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博　士　論　文　の　要　旨

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博士論文題名

A study on equilibrium form of tensegrity and development of contact analysis for its folding behavior
（テンセグリティ釣合解の特性と畳込みのための接触解析に関する研究）

This thesis has two main objective. One is to examine the characteristic of equilibrium solutions of tensegrity structure. Tensegrity has the basic rule not to connect compressional members each other and forms "self equilibrium" under the condition of zero gravity. The other is the contact problem with extremely large displacement which has to be considered when simulating the deploying and folding behavior of tensegrity.

It is known that the tensegrity has a lot of equilibrium solutions corresponding to one set of connectivity condition on the form-finding process. Thus, it may be difficult to achieve a feasible objective solution among the existing many solutions, even if using a very reliable geometrical nonlinearity analysis program. This thesis has focused on "tensegrity tower" which has so many bifurcate solutions. The path finding analyses using the tangent stiffness method have executed to classify the solutions by characteristic of the paths.

Moreover, the tensegrity is expected to apply it to space structures such as huge antenna, because it has flexibility and plural equilibrium solutions. In this thesis, a unique derivation for the element force equation has been proposed to simulate the contact behavior about two cases of the element-element contact and the node-element contact. The tangent stiffness method realizes the sure convergence and the exact solutions in this complex nonlinear case.

This thesis consists of all six chapters.

Chapter 1 is the beginning. The background, purpose and positioning of the research are mentioned, and then explanation about the configuration of the thesis is done.

In Chapter 2, the outline about the tangent stiffness method which is a geometrically nonlinear theory used in the thesis and the characteristic of its algorithm have been presented.

In Chapter 3, a computational example is shown to verify the accuracy and rationality of the tangent stiffness method, and the solution have been compared with FEM.

In Chapter 4, the characteristic of equilibrium solutions of tensegrity has been discussed by the result of form-finding analysis using the measure potential elements with a virtual stiffness. Here, at first, the review about the force density method which is generally used for form-finding process has been executed, and the difference with the proposed method in the thesis has been explained. Furthermore, the form-finding analyses have been executed exhaustively from the condition that the initial layout of the elements was changed little by little in the same connectivity. According to the computation, it has been clarified that there is

no correlation between the incidence of the solution and the total potential energy. Following to above, the path finding analyses of the tensegrity tower were executed to examine the characteristic of solutions on all the paths including bifurcate paths. Moreover, another computation has shown that the influence of gravity makes the equilibrium path complex.

In Chapter 5, the contact element for the folding simulation of tensegrity has been developed and the inspection of the validity and usability through several numerical examples has been executed. At first the element having the middle hinge which assumed the frictionless contact between the cables has been proposed. Using this element, even in case of the net structure under the complicated configuration that the plural contact points were generated on one element, the strict solutions have been obtained with stable convergence process. Furthermore, another the element force equation has developed for the contact problem between a node and a beam element. This element evaluates the influence of shear deformation to overcome the problem which occurs when a contact node approaches so close to the element edge. Consequently, the behavior that the contact point goes through the element boundary smoothly with sliding have been simulated exactly.

Chapter 6 is a conclusion, which generalizes the knowledge provided in each chapter and mentions about the future prospects.