Preface

Aims and Scope

Tensegrity structures are now more than 60-years old, since their birth as artworks. However, they are not "old" nor out of fashion! On the contrary, they are becoming more and more present in many different fields, including but not limited to engineering, biomedicine, and mathematics. These applications make use of the unique mechanical as well as mathematical properties of tensegrity structures in contrast to conventional structural forms such as trusses and frames.

Our primary objective in writing this book is to provide a textbook for self-study which is easily accessible not only to engineers and scientists, but also to upper-level undergraduate and graduate students. Both students and professionals will find material of interest to them in the book. With this objective in mind, the presentation of this book is detailed with many examples, and moreover, it is self-contained.

There are already several existing books on tensegrity structures; most of them present approaches to realization and practical applications of those structures. By contrast, this book is devoted to helping the readers achieve a deeper understanding of *fundamental* mechanical and mathematical properties of tensegrity structures. In particular, emphasis is placed on the two key problems in preliminary design of tensegrity structures—*self-equilibrium* and *(super-)stability*, by extensively utilizing the concept of force density and high level of symmetry of the structures.

Subjects and Contents

Tensegrity structures are similar in appearance to conventional bar-joint structures (trusses), however, their members carry forces (prestresses) even when no external load is applied. This means that their nodes and members have to be balanced by the prestresses so as to maintain their equilibrium. Furthermore, most tensegrity structures are intrinsically unstable in the absence of prestresses, and it is the introduction of prestresses that makes them stable. For these reasons, finding the *self-equilibrated configuration* and investigation of *stability* are the two key problems in the preliminary design of tensegrity structures.

Finding the configuration associated with prestresses, in the state of self-equilibrium, is called *form-finding* or shape-finding. It is a common design problem for tension structures, including tensile membrane structures and cable-nets. The problem is difficult because the configuration and prestresses cannot be determined separately as a result of the high interdependency between them. Further difficulties arise from the fact that tensegrity structures maintain their stability without any support.

A structure is stable if and only if it has the locally minimum total potential energy, or strain energy in the absence of external loads. Stability investigation of tensegrity structures is necessary because their stability cannot be guaranteed as can that of cable-nets or membrane structures carrying tension only in their structural elements. This comes from the fact that tensegrity structures are composed of (continuous) tensile members and (discontinuous) compressive members. Moreover, it is possible for tensegrity structures to be *super-stable*, which is a more robust stability criterion, if proper prestresses are associated with the proper connectivity pattern.

In this book, basic concepts and applications of tensegrity structures are introduced in Chap. 1. Chapter 2 formulates the matrices and vectors necessary for the study of self-equilibrium and stability. The analytical conditions for self-equilibrium of several highly symmetric tensegrity structures with simple geometries are given in Chap. 3. Chapter 4 defines the three stability criteria—stability, prestress-stability, and super-stability—and derives the necessary conditions and sufficient conditions for super-stability. The force density method, which guarantees super-stability, is presented in Chap. 5 for numerical form-finding of relatively complex tensegrity structures. Utilizing the analytical formulations for highly symmetric structures given in Appendix D, the self-equilibrium and super-stability conditions are derived for the prismatic tensegrity structures in Chap. 6 and those for the star-shaped structures in Chap. 7; both these classes of structures are of dihedral symmetry. Additionally, Chap. 8 presents the self-equilibrium and super-stability conditions for structures with tetrahedral symmetry.

At the end of the preface, we have to give our deepest thanks to our families, friends, and former and current students for their supports. Part of the work on symmetry has been conducted in close collaboration with Dr. Simon D. Guest of the University of Cambridge and Professor Robert Connelly of Cornell University; they showed us a new way to study tensegrity structures. Mr. Masaki

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Nagoya, December 2014 Jing Yao Zhang
Higashi-Hiroshima Makoto Ohsaki

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