HW1 Report

1. Introduction

Tensegrity structures have very wild range of applications. A tensegrity system contains various bars and strings, where bars could be compressed or stretched, and strings can only be stretched. A well-designed tensegrity structure can minimize the cost of material and maximize the flexibility while functioning well. In this homework-base report, a 2D and a 3D tensegrity known as Mitchell Truss and Non minimal prism with 4 bars respectively, are studied.

2. Mitchell Truss of Order 4

A Mitchell Truss of order 4 is consists with a Mitchell spiral of order 4 and its mirror image about y=0 in the cartesian coordinate or theta=0 in the polar coordinate. One of them are all bars and the other all strings, see Fig.1 for reference.

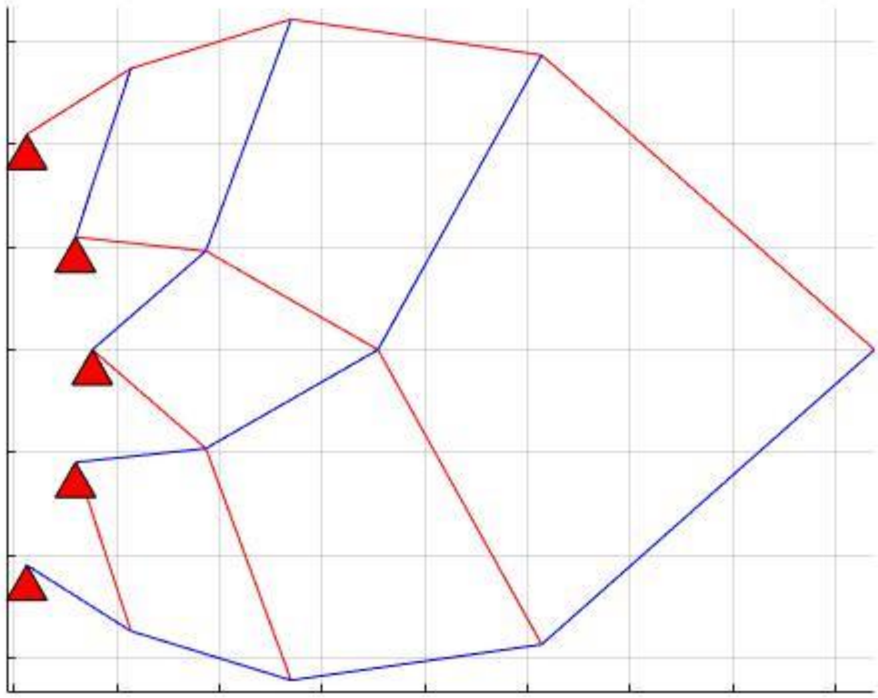

Fig. 1. Mitchell Truss of Order 4

The Mitchell truss of order 4 is consistent no matter which points are under loads, given that the 5 leftmost points (denoted as red triangles) are fixed. Being consistent means the structure is stable under the given loads. Various tests show that the truss is not potentially inconsistent under loads at arbitrary points in arbitrary directions.

Also, the structure is not underdetermined in all tests (Fig.2 as an example), which means the solutions to the stresses in the members are unique, so that the behavior of the structure is predictable.

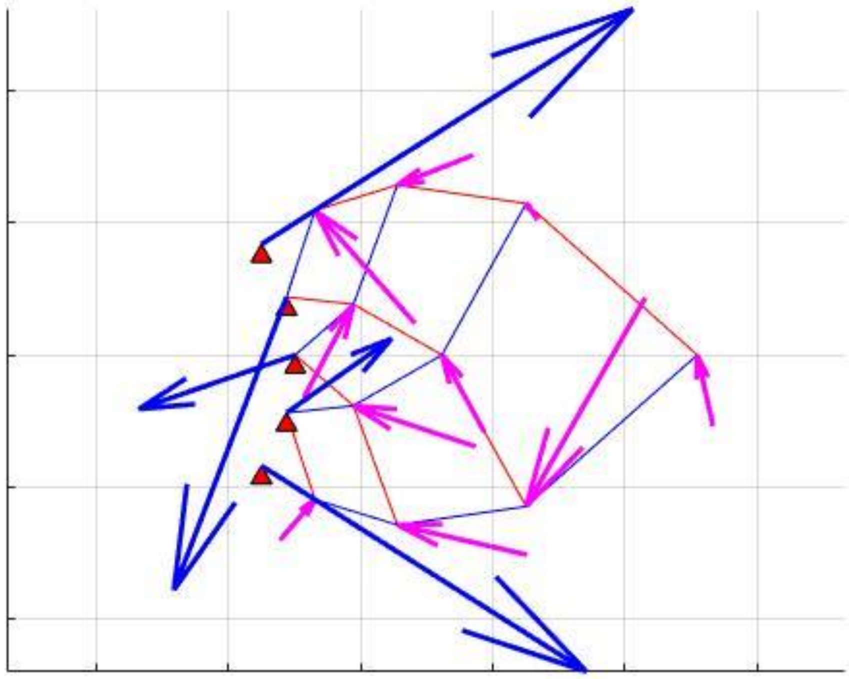

Fig. 2. The Truss under randomly applied outer forces (purple arrows), and its reactions (blue arrows)

3. Non minimal prism with 4 bars

A 4-bar non minimal prism is a twisted prism with 4 bars and rectangular as its top and bottom polygon, where the top and bottom rectangular has a phase difference of $\frac{\pi}{4}$.

In this report, the top and bottom polygon are taken as regular quadrangles, and with strings connecting each two nodes, as shown in Fig.3, where bars are denoted in red color.

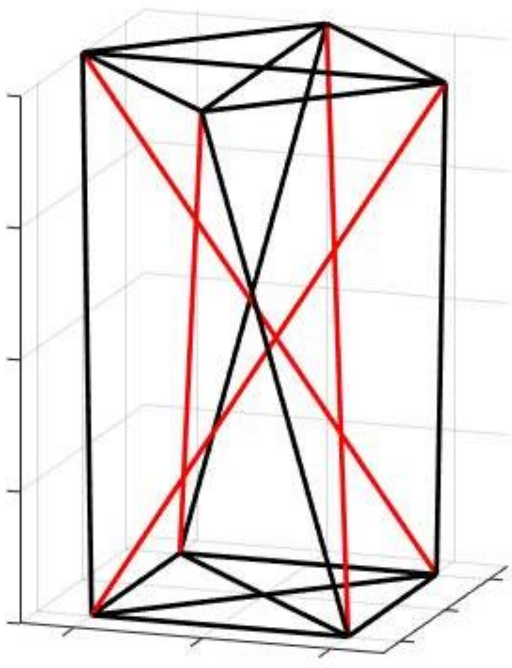

Fig. 3. Non minimal prism with 4 bars

Various tests indicated that the structure is potentially inconsistent, which means the structure has some “soft modes”, so that the structure may fail under some conditions. After few more tests, the stresses of this structure are only found to be determinant when forces applied on the nodes are evenly distributed and opposite at the top and bottom polygons (Fig.4).

Even if the stresses are determined, it is still underdetermined with 5 DOF, which means stresses in 5 members (in this case, strings) remains unknown because there are 5 linearly independent equations missing. A closer look of the tensile stress of the strings indicates that some of the strings are not even under tension. Needless to say, strings could not be compress, so the solution to the nominal loads are “fake” solutions. Moreover, the structure is not pretensionable, that is, we cannot even cancel the compressive stresses by applying tensile stresses when the structure is under zero load.

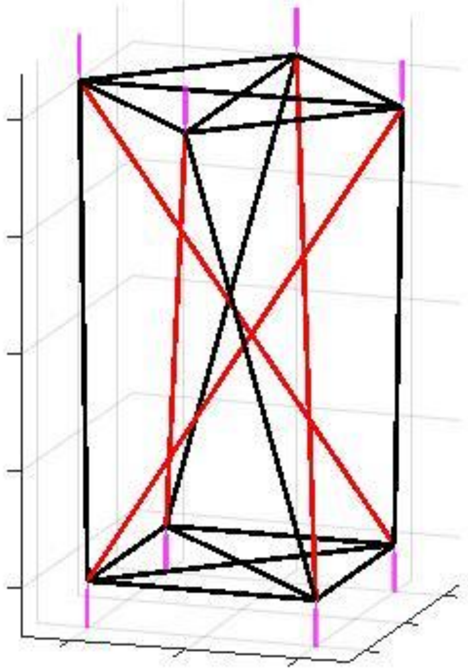

Fig. 4

4. Discussion

The Mitchell Truss of order 4 is a reliable and flexible structure with predictable behaviors. With 5 of its leftmost points shown in Fig.1 fixed, the truss can sustain under loads distributed arbitrary on its nodes, and such property makes it a reliable support for buildings.

The Non minimal prism with 4 bars, however, cannot sustain under any conditions. But since it is not completely inconsistent, fixing some of its nodes may be helpful.