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Structural Behavior of the Orb Webs Build by the Araneus Diadematus

Motivation

Light-weight structures have great potential for the future. Thereby the focus lies on more economic designs and increasing the efficiency of natural resources, which are becoming rarer day by day. Spiders already build such out-standing structures. Spider webs span large distances with a minimal material input. Understanding the structural behavior of orb webs can be beneficial for optimizing light-weight structures.

The investigations are based on the orb webs build by the native specie Araneus diadematus.

Influencing Factors

- Material Properties of Spider Silk:

Two different silks are used in the construction of a web. The first is the major ampullate silk, which has a high strength and can be extended up to 40%. The second is the flagelliform silk which distinguishes itself by an even higher strength and extensibility of up to 475%. The silk threads are strong enough to hold six times the body weight of the spider.

- Geometry:

A web is a circular structure with a central hub where all radial threads meet. The outer ring is formed by the frame threads. The structure is attached to the surroundings by the mooring threads. This is called the framework and is build up of the major ampullate silk. The flagelliform silk is used for the capture spiral, which is attached to the radii.

- Pretension:

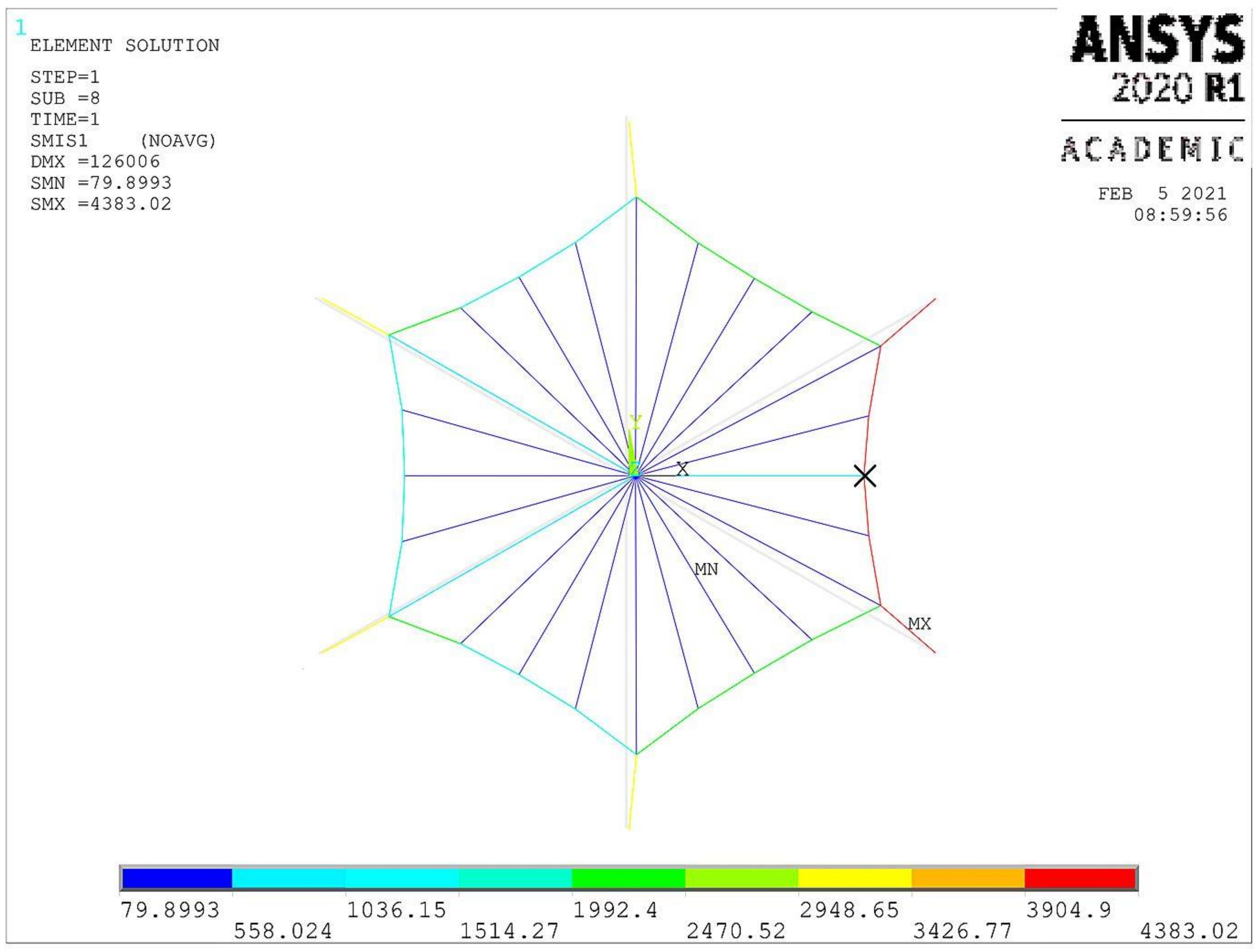
The spiders adds the pretension during the building process. Without pretension the web would be kinematic. The stability due to the pretension can be described with the P-Δ-effect.

Modeling of a Web in Ansys

The approach to investigate the structural behavior of an orb web is to model a web in a computer program using finite element analysis. For this purpose Ansys is selected. The data output is analyzed and further adjustments in the web are made. Finally, the examination of different loading conditions allows a better insight into the structural behavior.

Off Centered Load

The most informative load application point is on the frame. The following figure shows the deformed shape of the web as well as the normal forces occurring in the threads [μN]. Each color represents a small spectrum of values. The forces include the pretension forces as well as the load impact. Therefore, the increase in forces is considered in the following analysis.



The impact on a radial thread is distributed to the adjacent radial and frame threads. The frame threads pass the force on to the two adjacent mooring threads. Thereby they are pulled towards the force application point. This deformation mostly affects the frame threads of the whole web. This is reflected by the fact that they undergo a relatively high rise in tension. The frame threads distribute the impact to the opposing side. This reveals the importance of the opposite side. It is influenced in every loading condition. The impact either travels along the frame threads like in this case or through the hub. In conclusion, the pretension is essential in giving the web stability and the geometry allows excellent force distribution.

Literature

Wirth, E., & Barth, F. G. (1992). Forces in the spider orb web. *Journal of Comparative Physiology A*, *171*(3), 359-371.

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