Isogrid Membranes for Precise, Singly Curved Reflectors

Reinforcing meshes of fibers would prevent wrinkles and ripples.

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A new type of composite material has been proposed for membranes that would constitute the reflective surfaces of planned lightweight, single-curvature (e.g., parabolic cylindrical) reflectors for some radar and radio-communication systems. The proposed composite materials would consist of polyimide membranes containing embedded grids of high-strength (e.g., carbon) fibers. The purpose of the fiber reinforcements, as explained in more detail below, is to prevent wrinkling or rippling of the membrane.

A membrane single-curvature reflector is made by stretching a reflective membrane between frame ends that define the specified curvature (see Figure 1). The stretching is necessary to impart the stiffness needed to maintain the required curvature. Unavoidably, the stretching also induces a negative (compressive) strain, proportional to the Poisson's ratio of the membrane material, in the direction perpendicular to the stretch direction (see Figure 2). The negative strain gives rise to wrinkles and/or ripples. In the case of a precise radar or radio-communication reflector, the degradation of performance by ripples or wrinkles would be unacceptable.

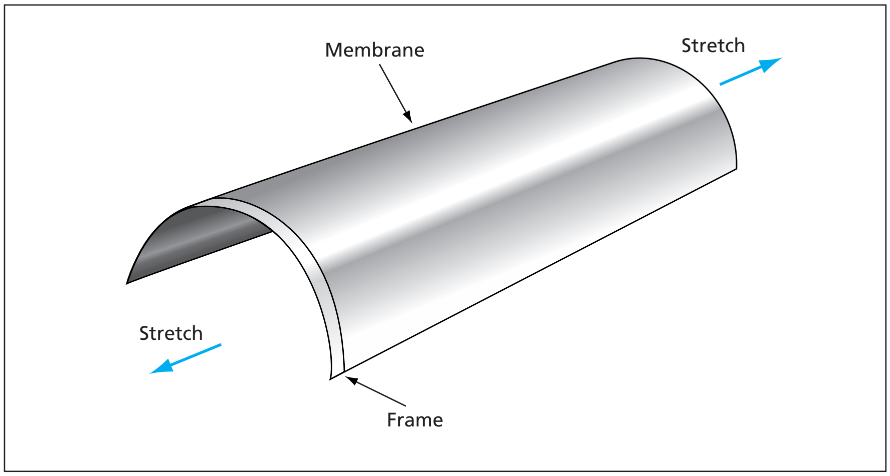

Figure 1. A **Membrane Is Stretched** between frame ends to make a lightweight, single-curvature reflector.

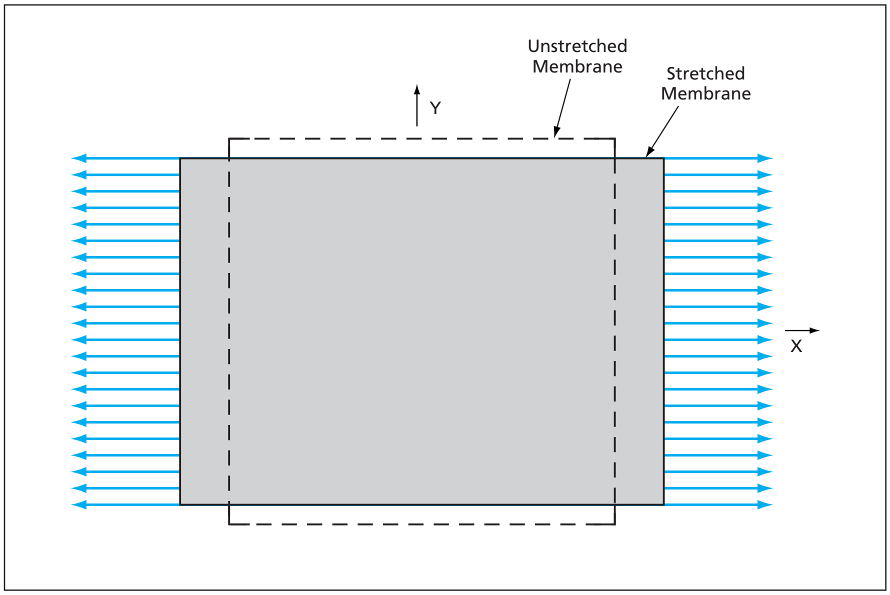

Figure 2. A **Membrane Stretched in the X Direction** contracts in the Y direction. The ratio between the Y contraction and the X stretch is denoted the Poisson's ratio of the membrane material.

In a membrane according to the proposal, the embedded reinforcing fibers would be meshed in an isogrid pattern. The design parameters of the fibers and the pattern would be chosen so that the fibers would carry much of the stretching load in such a manner as to reduce or eliminate the compressive strains in the directions perpendicular to stretching. From a macroscopic perspective, the reduction of compressive strains could be characterized by a corresponding reduction in the effective Poisson's ratio.

As a preliminary test of the proposal, computational simulations of effects of stretching were performed for two membranes, denoted the plain and isogrid membranes. The plain membrane was made of 2-mil (≈0.05-mm)-thick polyimide, without reinforcing fibers. The isogrid membrane was identical to the plain membrane except that it contained an embedded mesh of high-modulus-of-elasticity carbon fibers. In the simulations, the membranes were stretched along one direction and their contractions along a direction perpendicular to the stretching direction were observed. For the plain membrane, the contraction perpendicular to the stretching direction was 0.33 times the stretch: in other words, the effective Poisson's ratio was 0.33, which is typical of commercially available membrane materials. For the isogrid membrane, the effective Poisson's ratio was found to be 0.05. Further study will be necessary to determine whether this much reduction in the effective Poisson's ratio is sufficient to prevent wrinkles and ripples and whether further reductions in the effective Poisson's ratio can be achieved.

This work was done by Houfei Fang and Michael Lou of Caltech for **NASA's Jet Propulsion Laboratory**. *Further information is contained in a TSP (see page 1).*
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